MARYLAND ENERGY INNOVATION INSTITUTE

MEI² REPORT TO **The State of Maryland** *on the* **Present Status and Future Potential** *of* MARYLAND'S CLEAN ENERGY INNOVATION SYSTEM

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EXECUTIVE SUMMARY

Maryland's future economic success depends on the ability of its companies and institutions to innovate – creating a competitive advantage in new areas that provide opportunities for its companies and citizens. Over the past several decades, the state systematically and successfully invested in commercial development based on in-state discoveries and intellectual property in biotechnology. Now, Maryland's innovation in clean energy technologies provides another foundation on which the state can diversify and build a strong economic future.

In the past decade, Maryland's innovative scientists and engineers have taken strong advantage of new Federal programs (primarily from the U.S. Department of Energy) designed to encourage commercial development of new, cutting-edge clean energy technologies born from fundamental research. The recent establishment of the Maryland Energy Innovation Institute (MEI^2) is a testament to Maryland's ability to capture innovations from universities and focus them toward growth of in-state clean energy development and manufacturing firms. Based on the assessments carried out for this report, we conclude that with modest investment Maryland can build on existing strengths to create a thriving *Clean Energy Innovation System*.

The purpose of this report is to present recommendations on how Maryland can develop its *Clean Energy Innovation System* to strategically leverage clean-technology innovations that foster economic growth and complement the state's strong social commitment to energy efficiency, clean energy and the environment.

The growth of innovation-based clean-energy firms is important because this is the pathway to in-state manufacturing of new processes or products, with opportunities to sell or license these products nationally or internationally. The opportunities developed through the Maryland Clean Energy Innovation System will complement Maryland's existing programs for increasing deployment of commercially proven clean energy technologies, which typically do not focus on products developed and produced in state.

Opportunities and Challenges for Clean Energy

Maryland's opportunity in the clean energy innovation space is based on its strong technology foundations. The state leads in innovation (Maryland ranks 5th and 6th in recent rankings[1]) and has a strong base of research and development (R&D) capabilities (Maryland ranks 2nd among the states in annual per capita R&D expenditures, and 1st in per capita university R&D expenditures). Even though Maryland has historically not focused on clean energy as an economic development opportunity, it now has over 150 clean technology firms engaged in development and in-state manufacturing. These firms are clustered near the R&D hubs of the state around several Federal facilities, state university campuses, and also distributed across the state from Garrett to Worcester Counties, illustrated in Fig. ES-1. Among these firms there is a growing cadre that have taken advantage of new types of Federal support designed to accelerate commercialization of innovative clean energy technologies.

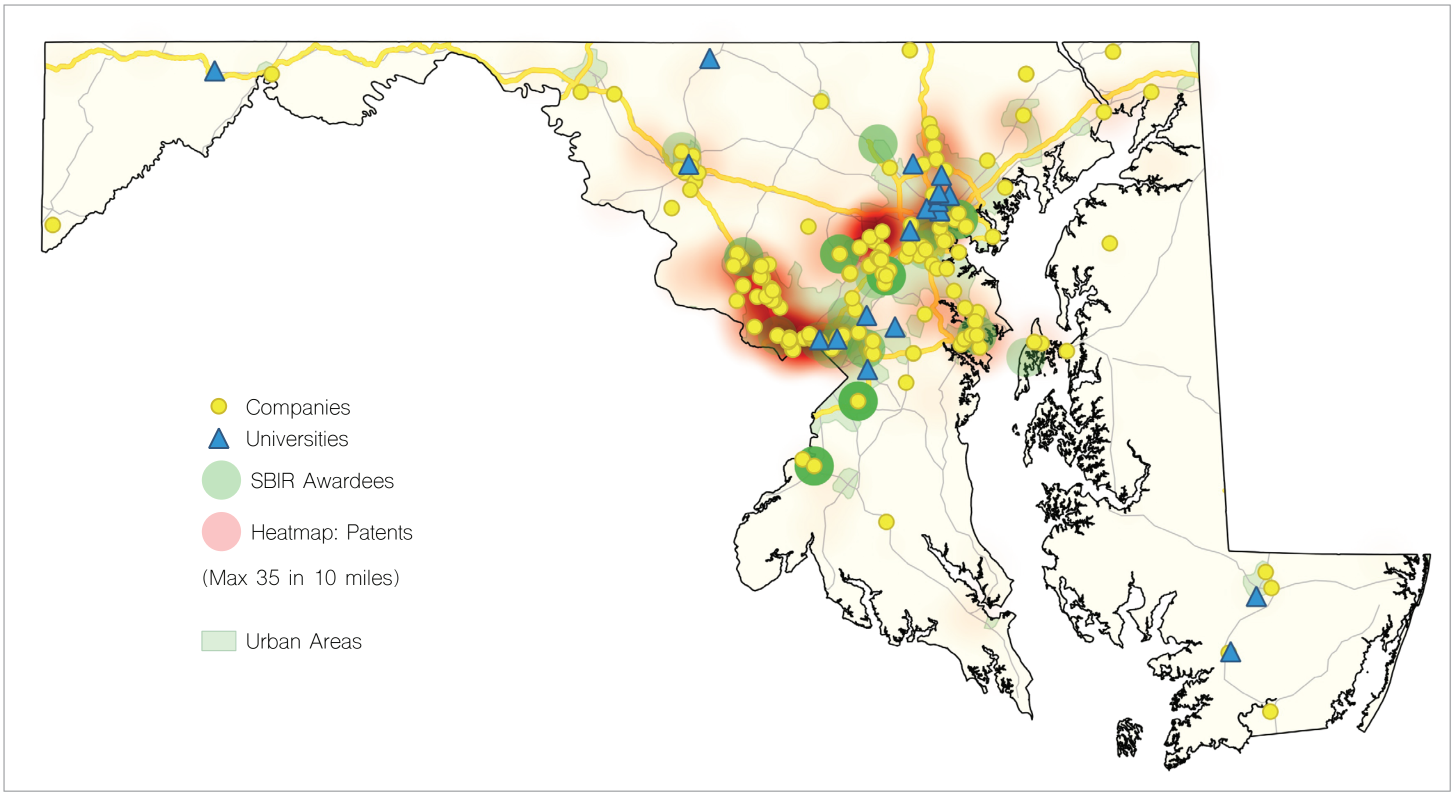
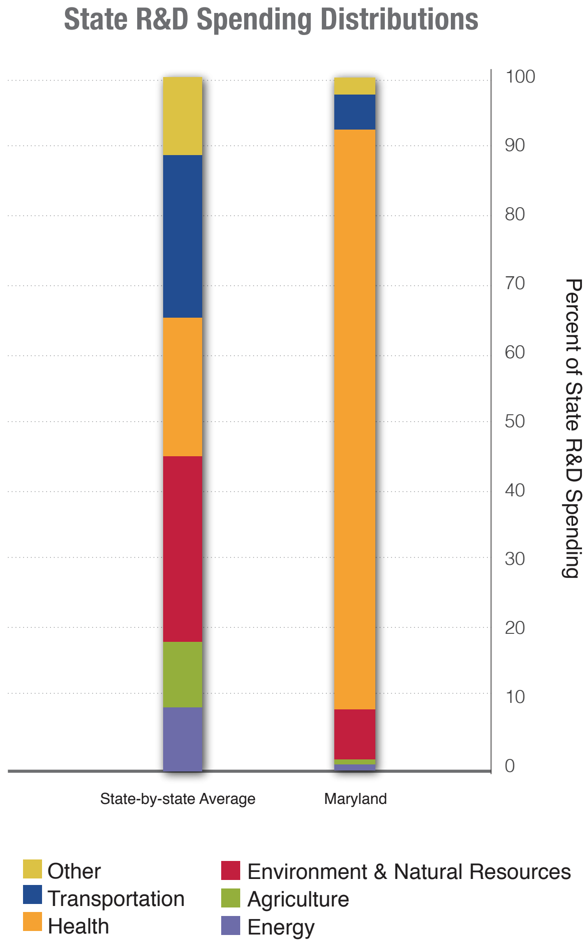


FIGURE ES-1: Distribution of Maryland firms (bright yellow dots) involved in development, commercialization and manufacturing of innovative clean energy technologies.



Even though Maryland has clear assets and capabilities, the state has until recently under-performed on what it could be doing to create new economic opportunities that leverage the state's strong commitment to clean energy and reduction of greenhouse gas emissions. The challenge is that Maryland has not focused on clean energy technology as a strategic approach to economic development with in-state commercial R&D and manufacturing.

FIGURE ES-2: State-reported R&D spending, averaged over 2013-2017.[2] Spending is reported to the NSF in the different categories indicated.

LEFT BAR: Across the fifty states, technology focus is widely distributed. Median state spending is $5.93 per capita.

RIGHT BAR: MD has placed a strong strategic focus on health-related R&D, which has crowded out support in other areas. MD's reported R&D spending is $4.66 per capita.

Recommendation 1

The state of Maryland should diversify its strategic economic development priorities to include multiple technology pillars, beginning by specifically mandating a *Clean Energy Innovation System* that supports innovation, development and in-state manufacturing of clean energy technologies.

The goals for the Clean Energy Innovation System should align with the state's social commitment to energy efficiency, clean energy and the environment, including reduction of greenhouse gas emissions.

Recommendation 2

Future legislative language regarding Maryland's Clean Energy Innovation System should reinforce a broad definition of clean energy to ensure that Maryland has the flexibility to support development of cutting-edge new approaches to meet the state's clean energy and greenhouse gas reduction goals.

Instead, Maryland has focused more narrowly than other states on a single area, health care-related technologies, as illustrated in Figure ES-2. While this positions Maryland to take advantage of one research strength, it disregards a broader set of opportunities for its citizens. Notably, Maryland ranks lasts among the states in the diversity of its technology support with its singular focus (85% of reported state R&D funding) on health-related technologies.

These observations, which are developed fully in the body of this report, lead to the first of this report's high-level recommendations.

Maryland has the opportunity to build its Clean Energy Innovation System by leveraging new Federal programs to accelerate the commercialization of clean energy innovation. These programs address the future of clean energy systems and support a diversity of technical areas. Maryland's innovative scientists and engineers have embraced this future-looking approach to clean energy as illustrated with the examples in the textbox. The companies shown are developing alternative fuels, energy storage, bio-agricultural advances, and the replacement of energy-intensive materials. This diversity of topics is consistent with global trends in clean energy innovation, which is now broadly defined to encompass technologies that enable greater energy efficiency, lower costs for clean energy technology and provide new approaches to reducing greenhouse gas emissions.

To address both Maryland's societal and economic goals for clean energy, a broad range of enabling approaches will be needed.

Examples of this breadth include:

- Energy storage, grid modernization and demand reduction
- Biotechnology in clean energy and clean agriculture
- Carbon dioxide removal, management and re-use
- Clean fuels and displacement of energy-intensive products
- Mobility – EVs, vehicle automation, transportation systems
- Integrated systems – AI and 'internet of things'
- New concepts in nuclear power to improve safety and lower costs

These observations on the technical opportunities in clean energy innovation, lead to the second high-level recommendation of the report.

Designing the Clean Energy Innovation System

Realizingthe goals of a thriving Clean Energy Innovation System for the state will require a planned structure of programs with metrics that can be used to gauge progress via intermediate goals. The general structure for moving innovative ideas into commercial products[3,4,5] is illustrated in Fig. ES-3. Different types of support are required at each stage of development, with particular focus on coordinated state programs to address the difficulties that firms have in moving from one stage of development to the next (often called 'valleys of death').

Clean Energy Innovation encompasses diverse technologies

From Nature | For The Future

INVENT WOOD is a start-up firm that is developing wood-based products that are strong and long-lived enough to replace energy-intensive building materials such as steel and concrete. The company is using innovative concepts developed at the University of Maryland-College Park. Their research publications on their new wood products such as transparent wood, super wood and cooling wood have attracted international interest, and led the team to establish their start up firm. The firm is part of a ~$4.0M ARPA-E award for scaling up and commercializing super wood led by the PI at University of Maryland, and also received ~ $1.25M SBIR funding from USDA and DOE Building Technology Office (BTO).

ETCH, INC is a start-up firm that is developing a clean and economical approach to producing hydrogen as an alternative to fossil fuels, using an innovative concept developed at Johns Hopkins University. The production method delivers valuable side products - solid carbon, heat, and water – along with hydrogen gas. The value of this new approach has been demonstrated through techno-economic analysis and market analysis. The firm was recognized as a finalist in the COSIA Natural Gas Decarbonization Challenge and has recently received an ARPA-E award of $3.7M for proof of concept and early commercial development.

ION STORAGE SYSTEMS is a young firm that is commercializing an innovative solid-state battery technology that solves battery safety concerns and increases the amount of energy a Li battery contains by 50%. The new technology is based on innovation by a University of Maryland – College Park team, leveraging $13M in Federal funds to date.

The development team progressed through patenting, obtained commercialization funding from DOE, NASA and Lockheed-Martin, and established supply chain partnerships with other Maryland firms. It has obtained Stage A Venture funding of $8M, and is establishing its first production capability in the MEI²/MTECH incubator.

PLANT SENSORY SYSTEMS is a young firm that is expanding deployment of its advanced bio-agricultural technologies that reduce the need for energy-intensive pesticides, fertilizer, and improve crops that are feedstocks for the bio-energy industry.

The firm has been supported by incubation at UMBC, by DOE and NSF awards, by interactions with USDA, and has attracted private sector investors who have benefited from the Biotechnology Investment Incentive Tax Credit. The company has developed partnerships on the Eastern Shore and in Frederick. It also has developed relationships for licensing production to firms in other states and internationally.

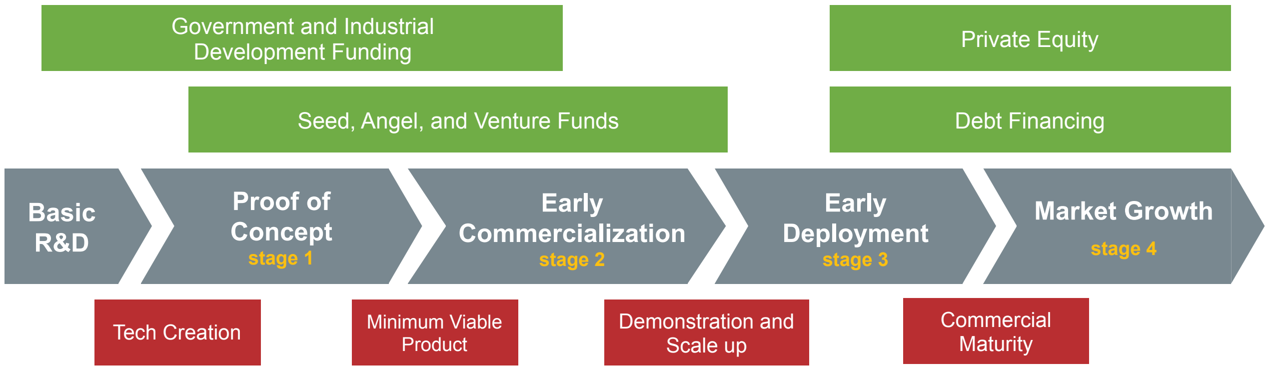


Figure ES-3: Innovation Commercialization pathway. Adapted from references ES 3-5.

In the early stages of development, Federal and industrial funding generally play the largest financial role. In these stages, state intervention in the form of technology incubators, 'seed funding' awards, and incentives for investors can be used to keep the development of innovative technologies in-state. In the later stages of development, state incentives, finance mechanisms and regulatory structures can play a large role in expanding markets into which emerging technologies can grow. In our assessment of the Maryland Clean Energy Innovation System, we have used this structure to quantify state financial commitments at different stages as illustrated in Fig. ES-4.

Maryland provides support at each of these stages of development. In stage 4, the state support of energy efficiency programs through EmPOWER provides incentives for well-established commercial efficiency products. In stage 3, the Maryland Energy Administration (MEA) supports programs to increase deployment of renewable energy and energy efficient technologies. However, the authorizations for EmPOWER and MEA do not include supporting the development of innovative in-state firms, so their impacts in creating market-pull for new technologies does not prioritize or specifically encourage the use of products from in-state manufacturing firms. Programs at MTech and TEDCO, designated for early-stage support for any technology area, have provided some funding for early stage clean energy innovation, with strong year-to-year variability.[6] Prior to the establishment of MEI[2] (which, beginning in 2018, provides $400k/yr of seed funding to help MD firms move from stage 1 to stage 2) and MCEC (which provided an average of $329k/yr of stage 3 support over 2013-17), there was no support directed specifically toward clean energy innovation. One key observation from this report's assessment is that the various agencies involved at different stages of the pipeline operate independently. Lacking coordination among these programs, Maryland's Clean Energy Innovation System does not sufficiently support the clear commercialization pathway illustrated in Fig. ES-3 or deliver the full benefits that would be possible if the different areas of state spending shown in Fig. ES-4 were strategically balanced and coordinated. This observation leads to the third high level recommendation of this report, which is shown on the facing page.

To develop options that are well suited for Maryland, we selected three states for comparison: Colorado, New York and Connecticut. These states have innovation and R&D rankings similar to Maryland's, but stronger outcomes in clean energy innovation. One example, shown in Table ES-1, is the number of clean tech firms per million people in the state: Maryland has significantly fewer clean tech firms than would be expected based on its innovation and R&D strengths.

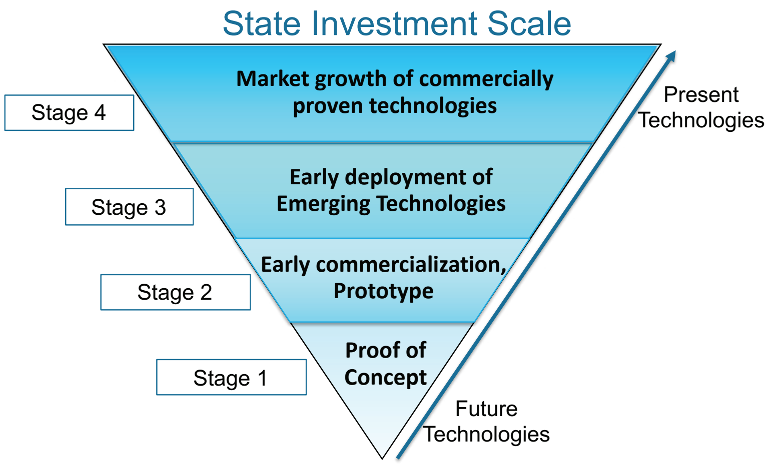


Figure ES-4: Stages of innovation, development and commercialization

In assessing the factors underpinning the other states' successful outcomes, we considered developmental support (e.g. providing support through infrastructure and mentoring), as well as direct financial support. Colorado has built on its entrepreneurial culture to develop strong developmental support for early stage clean energy firms. Colorado coordinates a set of support programs offered through universities, non-profit organizations and the Colorado Office of Economic Development and International Trade (CO-OEDIT). In New York, New York State Energy Research and Development Authority (NYSERDA) operates an integrated energy innovation system that incorporates a strong support system of incubators, business mentoring, as well as test facilities and demonstration options for in-state firms. Connecticut's clean energy approach is strongly influenced by its large industrial base, and extensive use of tax incentives, and doesn't provide clear lessons for Maryland's Clean Energy Innovation System. Maryland at present has no developmental program of support specifically designed to meet the needs of innovative clean energy firms.

The MEI^2 has demonstrated, by establishing the Center for Research in Extreme Batteries (CREB), how Maryland may provide developmental support through partnerships with local Federal laboratories and industry, in this case to advance clean energy innovation. Further progress in developing a clean energy innovation support infrastructure, similar to those successful in NY and CO, is possible by building on Maryland's system of biotechnology-focused infrastructure and mentoring approaches. The University of Maryland System's MTECH and UM Ventures, and Johns Hopkins' Technology Ventures all provide support for commercialization of University innovations, with a historical focus on biotechnology.

Recommendation 3

The State should designate a responsible agency to provide coordination among the agencies that need to be involved in delivering the outcomes expected of the state's Clean Energy Innovation System: Department of Commerce (DOC), Public Service Commission (PSC - EmPOWER), Maryland Energy Administration (MEA), Maryland Energy Innovation Institute (MEI^2), Maryland Clean Energy Center (MCEC) and Maryland Technology Development Corporation (TEDCO).

States	ITIF Innovation Potential: State Ranking	Number of clean tech companies per million people*
MD	6th	16
CO	7th	51
NY	11th	26
CT	10th	32

Table ES-1: Innovation scores and number of clean tech companies per unit (1 million people) population for the comparison states. (firms comparison based on I3 database).

Recommendation 4

As part of the state's Clean Energy Innovation System MEI² should be tasked and funded to deliver developmental support in the form of additional infrastructure and mentoring specifically tailored to the needs of early-stage clean energy firms, using partnerships with MCEC, TEDCO and University venture programs.

TEDCO recently supplemented this developmental support with a state-wide Incubator Assistance Program and a SBIR/STTR [7] proposal lab. With the establishment of MEI², there is now the opportunity to expand these programs to include clean-energy specific programs as part of Maryland's Clean Energy Innovation System. This leads to the fourth high-level recommendation of this report.

This report's comparison with other states' clean energy innovation systems also includes an assessment of direct state funding in the four stages of the clean energy commercialization. The outcome of that assessment is shown in Fig. ES-5. All three comparison states – Colorado, New York, and Connecticut provide more direct funding per capita on early stage clean energy technologies (stages 1 and 2) than Maryland. New York spends three times more (200% more) Colorado 50% more, and Connecticut 25% more per capita. Prior to 2018, Maryland's average early stage support of $0.33/capita did not include any funding targeting in-state firms developing clean energy innovation[8]. Maryland also has an anomalously high ratio[9] of support for market growth (stage 4) compared with early deployment of clean energy technologies (stage 3).

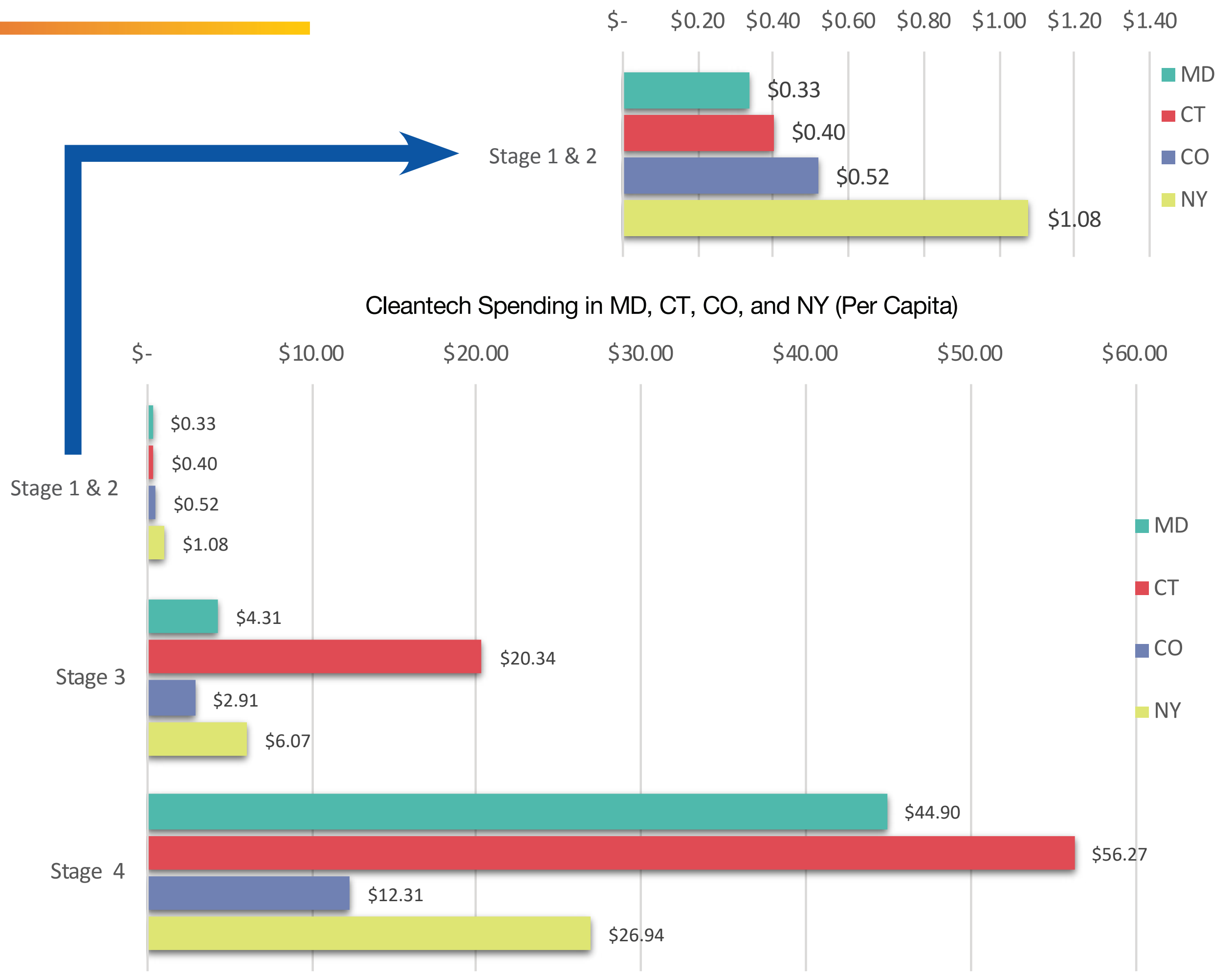


Figure ES-5: **Direct clean energy spending (per capita) relevant to commercialization in each of the comparison states, assessed as described in Appendices A and E. Stage 1 & 2 are early development (prototype development and early commercialization). Stages 3 & 4 are later stages of development (early deployment and market growth). Values are averages over several years of funding between 2013 and 2018 for each state. For Maryland the average is for 2013-2017. Values represent assessment of spending in the commercialization stages of Fig. ES-3 & 4, and thus do not represent all the energy-related spending in any of the states.**

New York's and Colorado's strong outcomes in number of clean energy firms can be reasonably attributed to the combination of their developmental support and their higher direct funding levels for early stage clean energy innovation. These observations, which are more deeply presented in Section III of this report, lead to the fifth high-level recommendation.

Expanded support to establish an integrated Maryland Clean Energy Innovation System will require specific metrics, with a well-defined time-line. A clear metric for the Clean Energy Innovation System is to significantly increase the number and productivity of Maryland's clean energy firms. Given this report's assessments (see Section III) of clean energy firms' time scale for commercial development and private sector funding, it is reasonable to set a ten-year goal to double the rate of new clean energy firms formed each year[10] and cut in half the rate at which these firms fail. Progress against this goal should be based on intermediate metrics including increased levels of Federal funding for commercialization, increased rate of new-company formation, increased levels of private sector funding per company and more rapid and more successful commercial growth. This outline of goals and metrics is the basis for the report's sixth high-level recommendation.

Each of the recommendations above is explained more fully in the report, sections I-III, along with expanded descriptions of implementation mechanisms for each. Based on understanding developed during preparation of this report, we also recommend further assessment of two topics related to later stage spending, as outlined in recommendations 7 and 8.

Recommendation 5

As part of the state's Clean Energy Innovation System, MEI² should be tasked and funded to expand early-stage innovation funding for clean energy firms to a per-capita funding level intermediate between Colorado and New York. MEI² should coordinate this program with TEDCO, MIPS, and University venture programs.

Recommendation 6

The program to create a thriving Clean Energy Innovation System in Maryland should be managed in 5-year stages and assessed against quantitative metrics including growth in firm number, Federal and private sector funding per company, and rate and extent of commercial maturation.

Recommendation 7

Given Maryland's unusually low level of support for early deployment of new clean energy technologies, compared with support for mature technologies, the state should require an assessment of the potential for reallocating some EmPOWER funds for emerging clean energy technologies that may provide expanded consumer benefits.

Recommendation 8

The state should require an assessment of the potential for expanded impact of EmPOWER funds by using green finance mechanisms (such as PACE[11], CPACE, Green Bank) for market growth of established clean technologies.

Funding Recommendation 1

The state should modify its present Investment Incentive Tax Credits[12] and associated TEDCO Investment Funds[13] to support investments in clean energy technologies. DOC, TEDCO and MEI² should be jointly responsible for delivery of Maryland's Clean Energy Innovation System goals through these programs.

Funding Recommendation 2

The state should modify the present allocation of the Strategic Energy Investment Fund[15] (SEIF) to include a specific allocation of up to 10% of the Fund's budget to support the Maryland Clean Energy Innovation System, with a renewed authorization considered in 5 years based on demonstrated progress toward goals. Of the reallocated funds, $4.5M should be allocated to the Maryland Energy Innovation Fund (MEIF).

Funding for Maryland's Clean Energy Innovation System

Maryland has successfully used a mechanism of combined tax incentives for investment, dedicated funding through TEDCO, and indirect support via university and other non-profit incubator services for commercialization of innovation in biotechnology. Similar support is necessary if Maryland's Clean Energy Innovation System is to meet a key goal of increasing private sector investment and related firm maturation for clean energy firms in Maryland. To accomplish this without new demands on the general fund, and in the spirit of Recommendation 2 (increasing the technology diversity of Maryland's technology-based economic development goals), our first funding recommendation addresses diversification of Maryland's investment incentives.

Funding Recommendation 1 is specifically needed to support the goal of increased private sector investment for Maryland's portfolio of clean energy companies, and thus to increase the rate of successful outcomes for these in-state firms.

In the first two years of operation of, with an operating budget of $600k/yr for stage 1 and 2 activities[14], MEI² has provided seed support to innovative clean energy firms from Johns Hopkins University, University of Maryland Baltimore County and University of Maryland College Park and has demonstrated the utility of developmental support in establishing the Center for Research in Extreme Batteries, a consortium of University, Federal Lab and Industrial partners. As discussed above, to deliver the required benefits to the state, both such early-stage support and developmental support must be expanded and coordinated with other support services and state programs for early deployment and market growth stages. This expanded, coordinate effort is essential to delivering an effective Clean Energy Innovation System. This leads to our second Funding Recommendation.

The purpose of requested funding for the MEIF is outlined in Funding Recommendations 2a, 2b and 3. Using $3M/yr of these funds MEI² will provide expanded direct funding and clean-energy-focused developmental support for innovative Maryland clean energy firms as per Recommendations 4 and 5. The experience with MEI²'s first two years of providing direct support in the form of seed grants has shown the value and opportunity of supporting of more very early stage concepts, as well as firms that have demonstrated success in the first year. At the present level of available seed funds, at most four early stage firms or one or two more-advanced firms can be supported in a given year. In addition to seed grants, funds are needed to help young firms develop partnerships with established firms or participate in funding opportunities that require they provide matching money. Often this is an unsurmountable obstacle to young firms, resulting in unnecessary company failures. State support for such matching provides leverage for growth.

Funding Recommendation 2a's allocation of additional support of $2M/yr for seed funds, partnerships and matching would increase Maryland's level of stage 1 & 2 support (as per Fig. ES-4) by $0.29 per capita. If the level of clean energy innovation support from MIPS and TEDCO continues at its recent average rate ($0.33 per capita), this would bring Maryland's direct early stage funding (stages 1 & 2 as per Figures ES-4 and 5) to $0.63 per capita. This is 20% higher than Colorado's value of $0.52 per capita and 40% lower than New York's value of $1.08 per capita.

Developmental support, which is the focus of recommendation 2b, when designed for the challenges clean energy firms must address, makes a crucial difference in the success of young firms. Developmental support includes:

- Mentoring in technical and business issues essential to commercialization
- Space (incubator) and seed funding
- Networking to develop supply chains, early markets and investment opportunities
- Networking and incentives for partnerships with established businesses
- Guidance in accessing Federal, state and local incentives and funding opportunities

In addition to the direct support of the Maryland Energy Innovation System under funding recommendations 2, 2a, and 2b, the reallocation of SEIF funds to MEIF should also include increased support for MCEC's outreach and finance activities, which are an important resource for clean energy innovation in the state. In particular, MCEC should use its financing and bonding authorities to support in-state clean energy manufacturing firms in stage 3 (early deployment) through opportunities to test and demonstrate their products in real applications.

Funding Recommendation 2a

Of the requested allocation from the SEIF to MEIF, $2 M/yr should be designated for expanded direct support of innovative clean energy firms through the *Clean Energy Seed Fund* and the *Partnerships and Matching Fund.*

The expanded *Clean Energy Seed Fund* will provide awards to early stage innovation projects and later stage projects that have demonstrated strong potential to leverage the seed funds to attract additional investment. *The Partnerships and Matching Fund* will provide awards for development of partnerships with industry or Federal laboratories and to provide matching funding for clean tech firms applying for MIPS funding or other programs that require matching funds.

MEI^2 will lead in coordination with DOC, MCEC, TEDCO, and University Venture programs, and all will be jointly responsible for delivery of Maryland Energy Innovation goals through the seed and matching programs.

Funding Recommendation 2b

Of the requested allocation from the SEIF to MEIF, $1 M/yr should be designated for developmental support of Maryland clean energy firms through an innovation acceleration program.

MEI^2 will lead and work closely with MCEC and TEDCO to provide awards to develop effective programs at Universities and other sites across the state. MEI^2, MCEC and TEDCO will be jointly responsible for delivery of Maryland Clean Energy Innovation System goals through the innovation acceleration program.

Funding Recommendation 3

Of the requested allocation from the SEIF to the MEIF, $1.5M/yr should be designated for support for MCEC outreach programs and for use of MCEC's financing and bonding authority to leverage stage 3 deployment of MD-developed clean energy technologies.

SECTION I: INTRODUCTION

The economic opportunities due to growing development and deployment of clean energy technologies are strong.

Worldwide, new investments in clean energy have exceeded $300 Bn annually in every year beginning in 2014,[16] with more than $50 Bn/yr in the United States. Venture investments, which are a significant source of support for the early stages of commercial deployment, have grown steadily from global levels of just above $12 Bn/yr in 2014 to more than $30 Bn in 2018[17]. For states such as Maryland, where the statewide societal commitment to clean energy is far more homogeneous than the US overall, as illustrated in Figure I-1, the growing world market provides a natural opportunity to develop correlated economic development opportunities.

Maryland is well positioned to support economic development through innovation because of its strong research and development (R&D) capabilities, university system, and educated workforce. In the past decade, Maryland University teams and small firms have been successful in attracting funding under new Federal funding programs designed to move innovative clean energy technology concepts into commercialization, as illustrated in Section I.C and in Appendix C. Such programs have demonstrated impact and attracted growing Federal budgets[19].

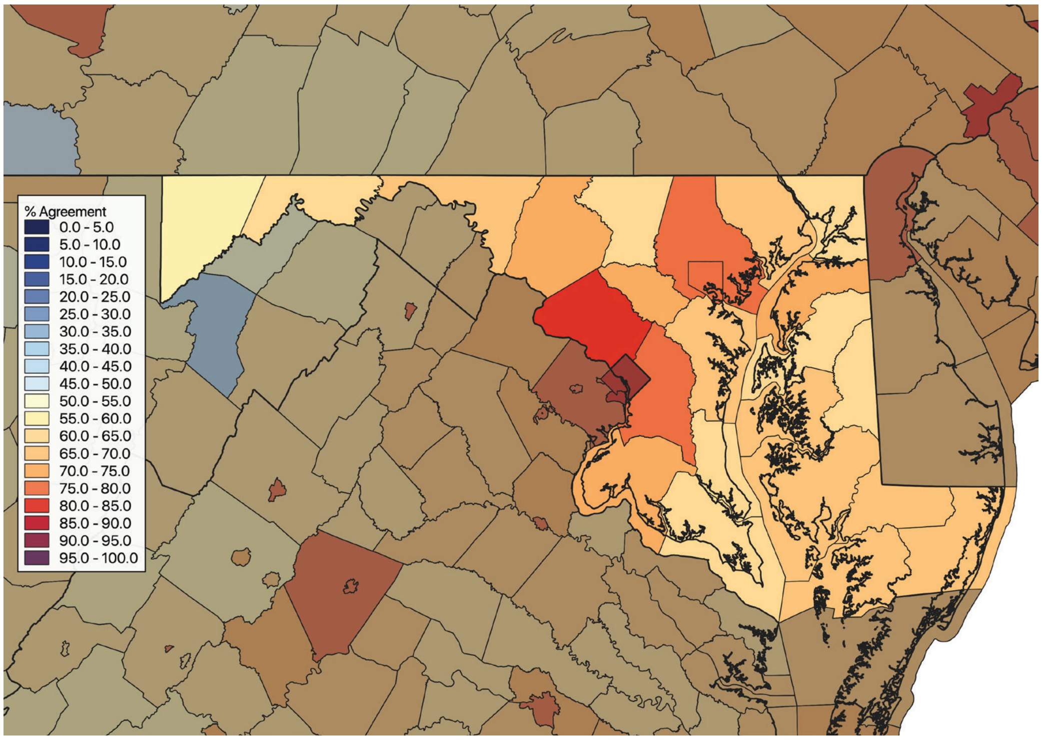


Figure I-1: Maryland public opinions about climate change issues are more homogeneous than in the US overall, from the Yale Climate Opinion surveys.[18] Map illustrates that agreement with a policy to "Set strict CO_2 limits on existing coal-fired power plants," ranges from 54%-79% by county. Across the US, county-by county agreement with this statement ranges from 37%-80%.

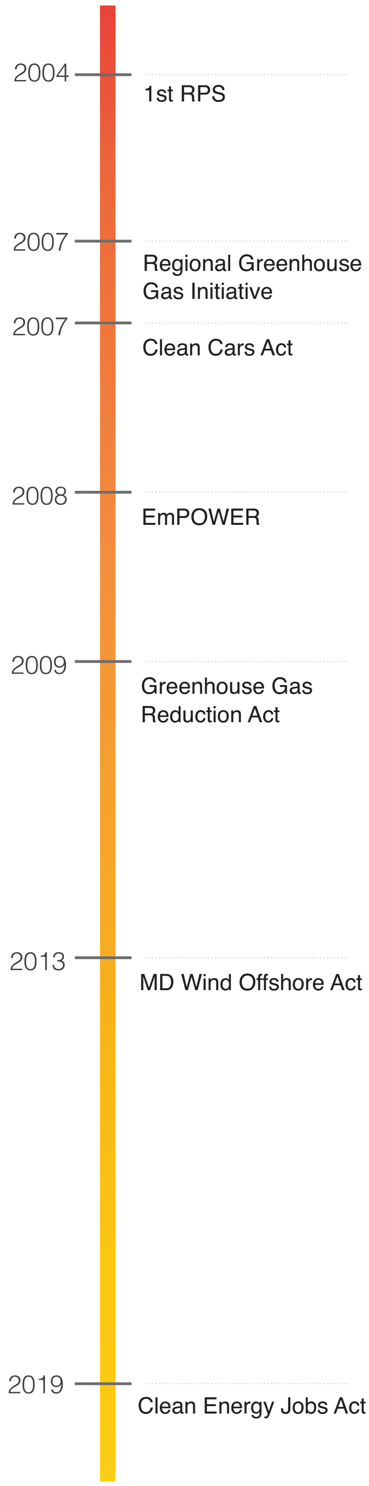
In this report, which is required under Senate Bill 313, Chapter 365, "An Act concerning economic development – Maryland Energy Innovation Institute," we will assess the status of clean energy technology innovation in Maryland and its potential to expand the benefits of Maryland's already-strong commitment to clean energy. In the following sub-sections of this introduction we outline the context provided by Maryland's clean energy policies, its strengths in research and development and technical innovation, and goals for increased clean energy innovation and commercial deployment in Maryland. The overall goal of this report is to present recommendations on how Maryland can develop its *Clean Energy Innovation System* to strategically leverage clean-technology innovations that foster economic growth and complement the state's strong social commitment to energy efficiency, clean energy and the environment.

I.A Maryland Policy Context

Maryland has actively and directly engaged in incentivizing energy efficiency and renewable energy deployment. This is indicated by Maryland's early adoption of a renewable portfolio in 2004. In 2007, Maryland joined the Regional Greenhouse Gas Initiative, a market-based program to cut greenhouse gas emissions that issues allowances and sets up mechanisms for regional CO_2 allowance auctions and limits emissions of CO_2 from electric power plants[20]. In 2009, Maryland enacted the Greenhouse Gas Emissions Reduction Act, which established a statutory requirement to reduce emissions by 25 percent by the year 2020, and which has since been updated to require a 40 percent reduction of emissions from 2006 levels by 2030[21]. The EmPOWER Maryland Energy Efficiency Act of 2008 established a goal to reduce per capita electricity usage and peak demand by 15 percent by 2015[22]. It has been extended until 2023 with Senate Bill 185/House Bill 514[23]. Additional initiatives include the Clean Cars Act in 2007, and the Maryland Wind Offshore Act in 2013[24]. In 2019, Maryland passed the Clean Energy Jobs Act which requires 50% of electricity from renewables by 2030[25]. The Governor has subsequently proposed the Clean and Renewable Energy Standards plan to take Maryland to 100% clean and renewable electricity by 2040[26].

Maryland's policy projections will have profound impacts on the future of Maryland's energy system, in particular its electric power system – both the in-state and out-of state generation of the electricity consumed in state as shown in the text box[27], and the distribution system that supports delivery of electricity to Maryland's residential commercial and industrial consumers.

Maryland's clean energy aspirations have included aspirations for correlated state economic development, including "the possibility of becoming a world leader in the development of clean and renewable energy, alternative fuels, green building technologies and cleaner burning cars".[28] However, as we will discuss in Section II, the majority of Maryland's support for clean energy technologies has focused on deployment *without* attention to in-state development and manufacturing. The establishment of the Maryland Energy Innovation Institute in 2017[29] was a concrete step in recognizing the potential for drawing on Maryland's strengths in innovation to develop economic benefits correlated with Maryland's existing commitments to clean energy.



Maryland's Changing Energy System

Maryland's ambitious clean energy policies – including the Clean Energy Jobs Act and the Greenhous Gas Reduction Act – will result in major changes in electricity use in the state over the next decade. These changes will provide opportunities for economic growth based on in-state innovative technology firms in areas such as grid storage, grid optimization, power electronics, and new business models based on distributed, clean power. They will also affect the context in which the state's EmPOWER energy efficiency programs are renewed in 2024, with support for energy storage and electrification of transportation and heating becoming increasingly important.

The figure below presents historical electricity generation and imports by source, and future projections for 2025 and 2030 based on current policies. Additional policies beyond 2030, for instance the 100% clean electricity goal for 2040 embodied in the proposed Clean and Renewable Energy Standard (CARES), would require further changes to the electricity mix.

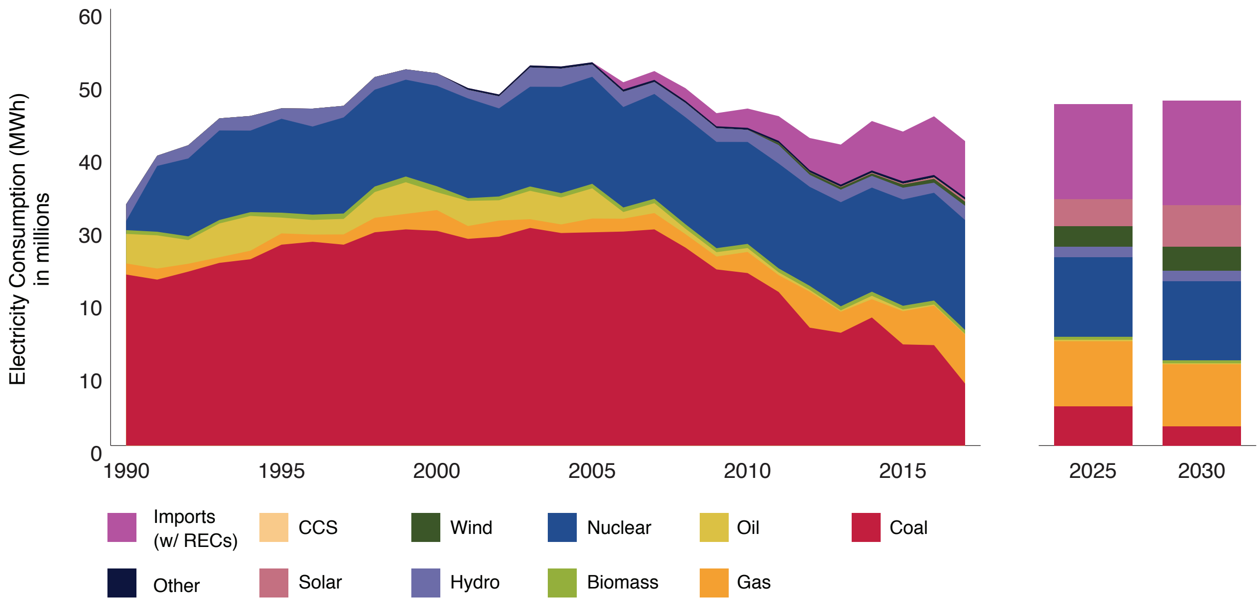


FIGURE I-2: Electricity consumption in Maryland including in-state generation and other imports ("other" category on the chart). Data from 1990-2017 are taken from EIAa, and imports with RECs are estimated by taking the difference between the RPS requirement and qualified in-state generation (and validated using reported compliance from the Public Service Commission). Projections for 2025 and 2030 represent a possible generation and import mix for complying with the state RPS. They are based on a simulation of current policies throughout the U.S. and modeled in the Global Change Assessment Model (GCAM). Qualified renewable generation increases from 16% in 2017 to 50% in 2030.

Maryland is a net importer of electricity, and historically the state has satisfied the majority of its RPS requirement with out-of-state generation. For example, in 2017, approximately 25% of renewable energy credits (RECs) retired were in-state, with the remainder coming from out-of-state electricity sources.d By investing in in-state clean energy technology development and deployment, and coordinating its EmPOWER and SEIF programs with the goals of the RPS and the Greenhouse Gas Reduction Act, Maryland could increase the share of its RPS satisfied in state, and bring more savings for consumers, jobs and investment to local communities.

I.B Maryland Strength in Innovation

Maryland ranks highly in technology innovation among the 50 states. The Bloomberg 2019 U.S. State Innovation index places Maryland 5th, surpassed only by California, Massachusetts, Washington and Connecticut,[31] and Maryland ranks 6th in the 2017 State New Economy Index.[32] One factor in Maryland's strong innovation rankings is its exceptional record of in-state R&D activity illustrated in Fig. I-3. Maryland ranks 2nd among the 50 states in annual average per capita R&D performed, and 1st in annual average per capita R&D performed in universities.[33]

Maryland has demonstrated the ability to use its R&D capabilities for economic development in the state through decades of support in the area of biotechnology[34]. However, Maryland has not expanded its success to other areas, including clean energy technologies. Instead, Maryland stands out among all the states in the US due the narrow technology focus in its state supported research and development, as shown in Figure I-4. Maryland's strong strategic focus on health-related R&D has resulted in on-average 85% of the state's total reported[35] R&D spending being allocated to health-related areas. As a result, R&D spending in all the other areas (agriculture, energy, environment and natural resources, transportation and other) are squeezed, leaving Maryland with the least diversity in its targeted technology areas among all fifty states.

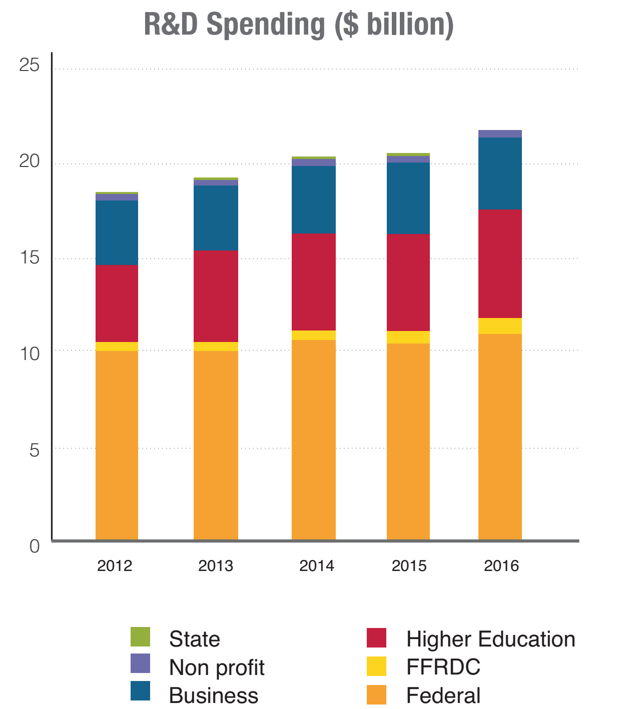


FIGURE I-3: R&D performed in Maryland 2012-2016. R&D, by Federal agencies, Federally funded research and development centers (FFRDCs), higher education, and business, non-profit and state sectors

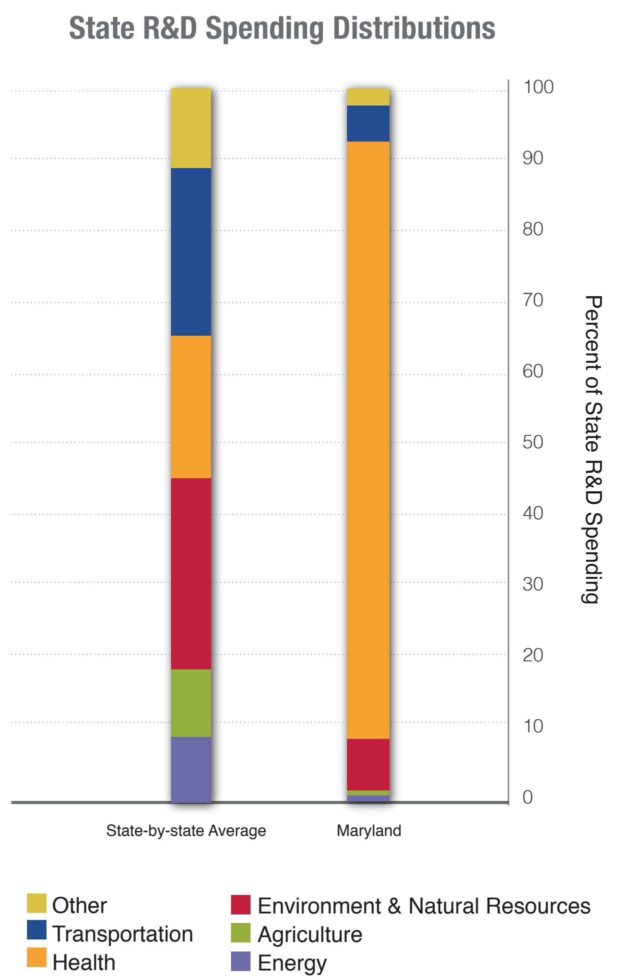


FIGURE I-4: State-reported R&D spending, averaged over 2013-2017. Spending is reported to the NSF[30] in the different categories indicated.

LEFT BAR: Across the fifty states, technology focus is widely distributed. Median state spending is $5.93/capita.

RIGHT BAR: Maryland has placed a strong strategic focus on health-related R&D, which has crowded out support in other areas. Maryland's reported R&D spending is $4.66/capita.

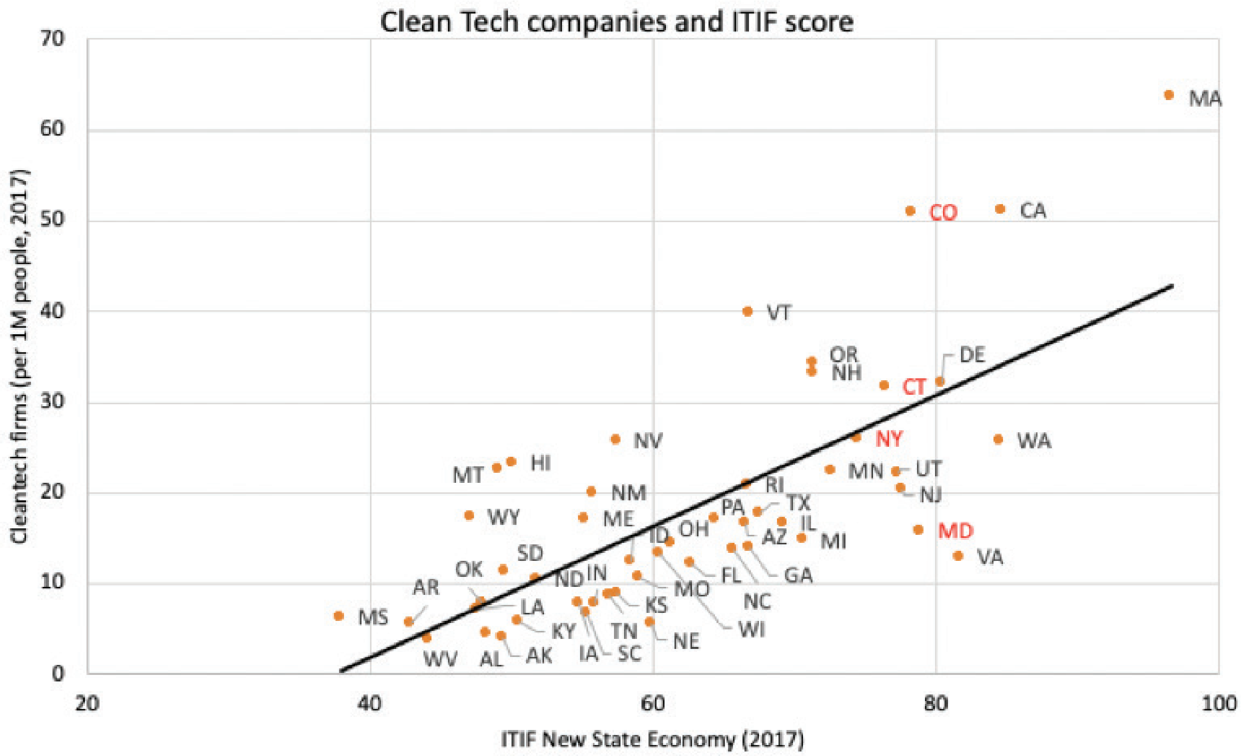


FIGURE I-5: The number of clean tech firms per million people in each, modified from the I3 data base (see Appendix D) versus the states' innovation rankings in the New State Economy Index. Maryland and three selected comparison states are highlighted with red text.

Given this lack of strategic state support for clean energy, it is not surprising that Maryland's innovation ranking is much lower in the Clean Tech Leadership Index[36] (15th in 2017), compared with its overall innovation rankings (5th and 6th in Bloomberg and ITIF scoring, see above). The number of clean tech firms per capita, which is a concrete indicator of a state's strength in energy innovation, is shown versus the State New Economy Index ranking in Fig. I-5. Despite Maryland's strong innovation capabilities, it falls significantly below other states with strong innovation rankings in the number of clean energy firms. Among the top 18 states in innovation ranking, only Virginia and Michigan fall lower than Maryland in the per capita number of clean energy companies in the state. In section III, we present a comparison of the structure, funding levels, and outcomes of Maryland's clean energy system with states of comparable innovation ranking, but stronger numbers of cleantech firms (NY, CT, and CO).

I.C Goals for Energy Innovation

The energy system is undergoing profound changes, in the world, in the US and in Maryland, and innovation provides us one mechanism to ensure that Maryland leads rather than only responds to those changes. The technologies needed to shape the future energy system will extend to include new areas such as:

- Energy storage, grid modernization and demand reduction
- Biotechnology in clean energy, agriculture and forestry
- Clean fuels and displacement of energy-intensive products
- Carbon dioxide removal and management
- Mobility – EVs, vehicle automation, transportation systems
- Integrated systems – AI and 'internet of things'
- New concepts in nuclear power to improve safety and lower costs

Four examples of the innovation potential demonstrated by young Maryland firms are shown in the textbox. A more extensive listing of Maryland firms that have demonstrated potential is provided in Appendix C.

Clean Energy Innovation encompasses diverse technologies

INVENTWOOD™
From Nature | For The Future

INVENT WOOD is a start-up firm that is developing wood-based products that are strong and long-lived enough to replace energy-intensive building materials such as steel and concrete. The company is using innovative concepts developed at the University of Maryland-College Park. Their research publications on their new wood products such as transparent wood, super wood and cooling wood have attracted international interest, and led the team to establish their start up firm. The firm is part of a ~$4.0M ARPA-E award for scaling up and commercializing super wood led by the PI at University of Maryland, and also received ~ $1.25M SBIR funding from USDA and DOE Building Technology Office (BTO).

ETCH

ETCH, INC is a start-up firm that is developing a clean and economical approach to producing hydrogen as an alternative to fossil fuels, using an innovative concept developed at Johns Hopkins University. The production method delivers valuable side products - solid carbon, heat, and water – along with hydrogen gas. The value of this new approach has been demonstrated through techno-economic analysis and market analysis. The firm was recognized as a finalist in the COSIA Natural Gas Decarbonization Challenge and has recently received an ARPA-E award of $3.7M for proof of concept and early commercial development.

ion Storage Systems

ION STORAGE SYSTEMS is a young firm that is commercializing an innovative solid-state battery technology that solves battery safety concerns and increases the amount of energy a Li battery contains by 50%. The new technology is based on innovation by a University of Maryland – College Park team, leveraging $13M in Federal funds to date.

The development team progressed through patenting, obtained commercialization funding from DOE, NASA and Lockheed-Martin, and established supply chain partnerships with other Maryland firms. It has obtained Stage A Venture funding of $8M, and is establishing its first production capability in the MEI²/MTECH incubator.

Plant Sensory Systems

PLANT SENSORY SYSTEMS is a young firm that is expanding deployment of its advanced bio-agricultural technologies that reduce the need for energy-intensive pesticides, fertilizer, and improve crops that are feedstocks for the bio-energy industry.

The firm has been supported by incubation at UMBC, by DOE and NSF awards, by interactions with USDA, and has attracted private sector investors who have benefited from the Biotechnology Investment Incentive Tax Credit. The company has developed partnerships on the Eastern Shore and in Frederick. It also has developed relationships for licensing production to firms in other states and internationally.

Because of the growing changes in the energy system, the goals for Maryland's Clean Energy Innovation System must include a broad perspective on the definition of clean energy. The text below proposes language to set goals that effectively encompass the future and evolving opportunities in clean energy innovation:

Goals Statement

The Maryland Clean Energy Innovation System shall be designed to leverage Maryland's strong position in innovation, Federally funded University research, and societal commitment to clean energy to deliver in-state commercialization and deployment of advanced clean energy technologies for the energy system of the future.

Clean energy innovation programs shall be structured to adapt to new technical opportunities and approaches, and will identify scientific advances and cutting-edge innovations. They will be tasked to accelerate innovations through the multiple stages of commercial development to deliver the economic and environmental benefits of:

1. **A growing number of commercial firms in Maryland that attract investment, generate revenues, and grow employment in development and manufacturing of the advanced clean energy technologies of the future**
2. **Increasing deployment of more effective technologies that contribute directly or indirectly to producing energy from clean and renewable sources, to improving efficiency in the use of energy, or to reducing emissions including greenhouse gases.**

I.D Structure of the Report

The remainder of this report is structured to sequentially address the three topics spelled out in the authorizing legislation:

Section II: the availability and efficacy of the use of funds for the development and deployment of clean energy technology in the State and the commercialization of that technology

Section III: the forecast need, if any, for additional funding or financing options for these purposes

Section IV: appropriate sources and levels of funding and financing options for these purposes

In Section II, we categorize Maryland's use of clean energy funds in terms of their application to the different stages of commercial development, and how well the different activities are integrated to support state economic development. In Section III, we use comparisons with other states that are comparable to Maryland in innovation capability to identify mechanisms and funding levels that have supported better energy innovation outcomes. We use these results to identify approaches to improve Maryland's clean energy innovation outcomes, and the resulting forecasted needs for state support. In section IV we briefly summarize the recommendations of this report and present a plan of action with better coordination among state agencies, clear metrics for desired improvements in Maryland's clean energy innovation outcomes, and options for funding and financing.

SECTION II

Availability and efficiency of the use of funding for clean energy development, commercialization and deployment

Here we address the first of the three topics requested for this report, evaluating "the availability and efficiency of the use of funds for the development and deployment of clean energy technology in the State and the commercialization of that technology." In making this evaluation, we consider the present Maryland energy innovation system in terms of the stages of commercial development beginning with innovative new ideas, and moving through entrepreneurial development of commercial practicality, and on to early deployment and then market growth. The basic steps in the pathway of a new technology from discovery to market[37,38,39,40] are illustrated in Figure II-1:

To be successful, an innovation system must address each stage individually, and also ensure coordination among the stages so that individual technologies have opportunities to move forward. In evaluating Maryland's Clean Energy Innovation System, we use the definitions and structure outlined in the textbox. The definitions are explained further in Appendix A.1.

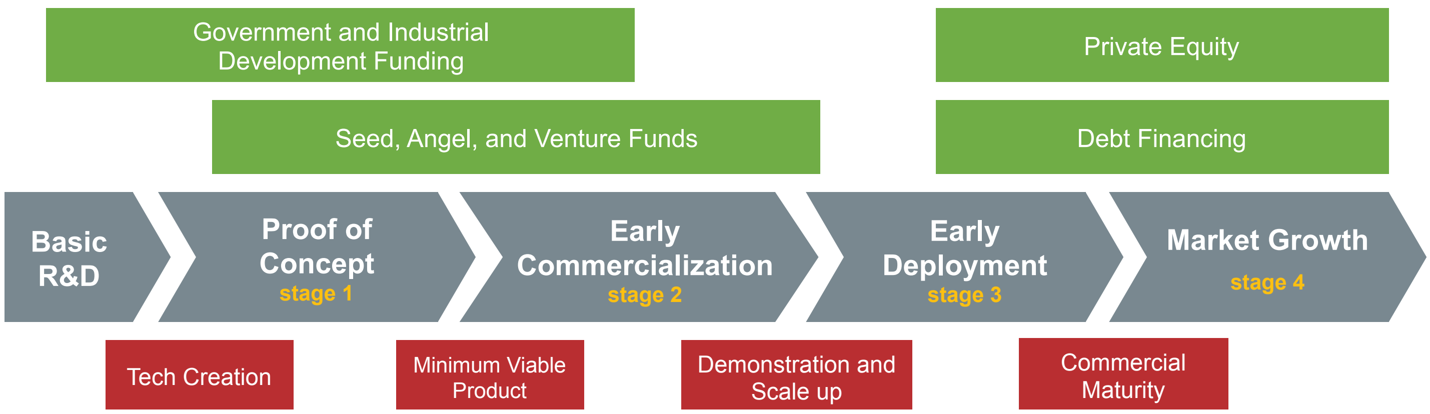


Figure II-1: Innovation Commercialization pathway. Adapted from references 37–40.

Defining the Stages of Development, Commercialization and Deployment

Proof of Concept: The early stage research that leads to innovative ideas is often supported by basic research grants, and the resulting ideas must be further developed to determine whether they have practical technical potential – this is the proof of concept stage. The potential of promising technologies is often lost in a 'valley of death' resulting from limited support to accomplish the transition into and through the next stage of development.

Early Commercialization: Demonstration of practical technical potential must be followed by development of practical commercialization potential, which may include developing supply chains, scale-up to manufacturing, identifying first markets, and demonstrating robust operations in a working prototype. During this stage of development, successful companies will begin to attract private sector investment.

Early Deployment: Further growth occurs as the companies demonstrate their first ('first-of-a-kind') manufacturing capability and begin to deploy products. Development costs require expanded private sector investment, which will be strongly influenced by assessment of the market pull for the product. The Early Deployment stage represents another 'valley of death,' where promising technologies often founder due to lack of the investment needed for growth.

Market Growth: Technologies that succeed in deploying a viable project will see production costs driven down due to the 'learning curve' resulting from further R&D and manufacturing experience, making their products more competitive. They will be able to attract loans to expand manufacturing and sales. Government regulations and incentives can impact the rate of market growth dramatically.

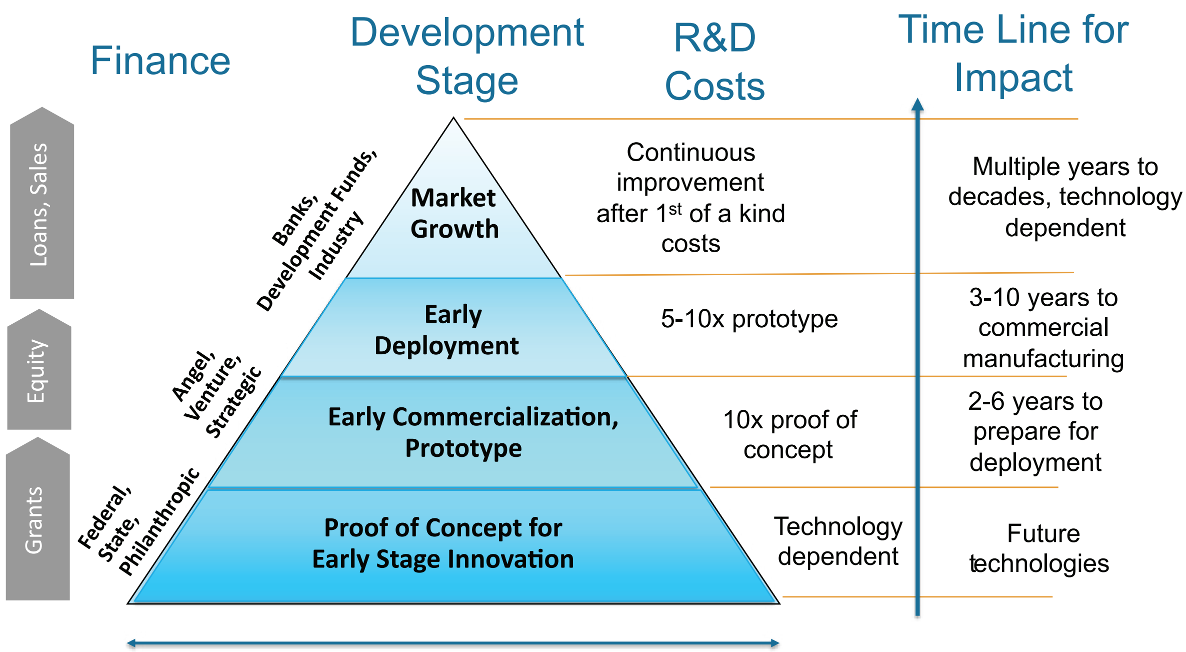


Figure II-2: The stages of commercial development from innovation to market growth. Success in this pathway is crucially dependent on transitions between the stages.

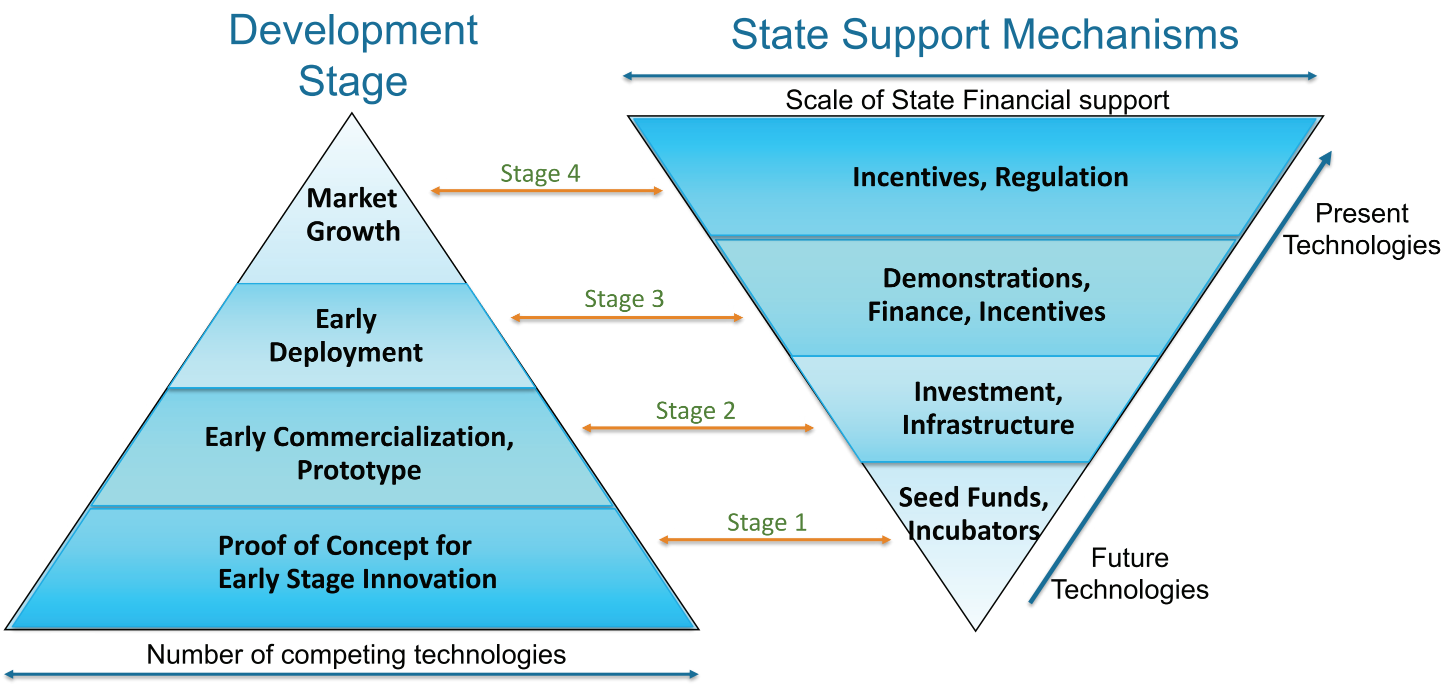


FIGURE II-3: Commercialization pathway triangles: Illustration of support mechanisms that are effective in accelerating the stages of commercial deployment of innovative clean energy technologies.

The stages of innovation for clean energy technologies can span a lengthy timeline because of the need to develop new scientific and engineering approaches, the scale of the market, and the presence of incumbent technologies that have achieved low costs even though they may not match the higher performance of the new technologies. Well-designed government policies and support can dramatically increase the rate of success of innovative clean energy technologies in crossing the 'valleys of death' and delivering their societal and economics benefits. The relationship between the technology stages and the corresponding levels of support is illustrated in Figure II-3.

At the earliest stages of development, the largest support is generally from Federal programs or industrial R&D. Smaller amounts of state funding, carefully invested, can provide leverage to help young firms compete successfully for such funding. In particular, early-stage innovators often benefit from support specifically designed to help them move from a basic research orientation to a pathway for commercial development. State programs such as seed funds and incubators that provide mentoring can help young team compete for Federal grants, such as those offered by Small Business Innovation Research (SBIR) or the Advanced Research Projects Agency – Energy (ARPA-E), that focus on commercial deployment. More advanced teams, who are working on early commercialization, benefit from further incubator support, seed funding and state investment support to ehnance their ability to attract private investments.

As technologies advance to the stage of early commercial deployment, support for demonstrations, low-cost financing, and other incentives can make the difference between success and failure for young firms. The presence of such support can also make the difference between keeping a company in-state and seeing it move, with its intellectual property, to another state, or even another country.

In the remainder of Section II, we will present:

Section II.A A quantitative breakdown of the funding provided by Maryland programs for clean energy in each of different development stages.

Section II.B Discussion of the efficacy of the funding structure to create economic benefits for the state.

Section II.C Discussion of the efficacy of the funding structure in the context of the health of Maryland's Innovative Clean Energy Firms.

Section II.D Summary of key findings from Section II.

II.A: Programs and Funding in Maryland's Clean Energy Innovation System

Many Maryland agencies are involved in addressing the state's commitment to environmental and consumer issues related to clean energy. Among these, we have reviewed the specific agencies whose programs have supported in-state commercial development and deployment of clean energy technologies as well as all of the programs supported by the Strategic Energy Innovation Fund (SEIF) and relevant EmPOWER programs. In the following, we roughly order these efforts according to their impact at different levels of the commercialization pathway, beginning with support for the development of proof of concept, and early commercialization for new innovations, then with efforts to increase the early deployment of emerging products, and ending with market growth of commercially-proven energy efficient and clean energy products. Appendix A.2 provides more detailed information about assessments of agency programs supported under the SEIF and programs supported under EmPOWER, and Appendix B lists the agency reports that were used in compiling information. In some cases, the reports were supplemented by information provided directly from an agency.

II.A.1 Support for Proof of Concept and Early Commercialization

Maryland Energy Innovation Institute (MEI^2) (Stage 1)

In FY2018, $1.5 M/yr in SEIF funds (2.0% of the SEIF funds) were allocated to the Maryland Energy Innovation Fund (MEIF) to support the programs of the Maryland Energy Innovation Institute (MEI^2) and the Maryland Clean Energy Center (MCEC) from FY2018 to FY2022. Of that funding, $600k/yr supports the Maryland Energy Innovation Institute.

MEI^2 is tasked to catalyze and develop clean energy technologies and facilitate the transfer of technologies into marketable products or services. It has established an Advisory Board and an Investment Committee with science, industry, government and economic leaders. In the two years since it was founded, MEI^2 has provided both developmental services and seed grants for early stage innovation and commercialization of clean energy technologies.

Among its developmental services, MEI^2 supports the Center for Research in Extreme Batteries, CREB, under a cooperative research and development agreement between UMD and the Army Research Laboratory. CREB provides opportunities for collaboration and support for researchers from Federal laboratories, universities and industries. MEI^2 has also engaged with the *Regional Manufacturing Institute of Maryland*[41] to enable introductions between researchers and Maryland manufacturing companies to develop local supply chain opportunities. The institute also provides mentoring and administrative support for University of Maryland based energy innovations being developed in partnership with local spinoff companies[42].

MEI^2's Energy Innovation Seed Grants are designed to "bridge the gap between academic transformative laboratory research results and prototype demonstrations to obtain investor interest".[43] Thus, we assign MEI^2's seed grants to the "Proof of Concept for Early Stage Innovation" category, which is the 1st stage in the commercialization pathway. MEI^2 has provided $400k in seed funding for each of FY2018 and FY2019 (see appendix C for the projects supported).

The Maryland Technology Development Corporation (TEDCO): Stage 1 and 2

TEDCO is a state program that was set up to promote technology and technology-based economic development in the state. It was established in 1998, and has historically had a strong focus on biomedical technologies. It is primarily supported through the state general fund, and also has revenue from external grants, royalties and investment earnings. TEDCO began making investments in debt and equity securities in 2011.

Some of TEDCO's funding programs, such as the Maryland Innovation Initiative[44], Technology Validation Program, and TEDCO & NIST Science and Technology Entrepreneurship Program (N-STEP) program are designed to move research conducted in Maryland onto a commercialization pathway. We assign such programs to Proof of Concept category, that is the 1st stage of development in the commercialization pathway.

Other TEDCO programs help the early commercialization of new technologies, such as Maryland Venture Fund, Technology Commercialization Fund, and Rural Business Innovation Initiative. We assign such programs to the "Prototype, Early Commercialization" category, that is the 2nd stage of the development in the commercialization pathway.

Over the past 5 years (Fiscal Year 2014-2018), Maryland Technology Development Corporation's average annual program spending for commercialization of in-state clean energy technologies was $897,800, 4.1% of its overall expenditures (average $22M/y), with $422,800 of that in the proof of concept stage, and $415,000 in for early commercialization.

Maryland Industrial Partnerships (MIPS) program (Stages 1 and 2)

MIPS is a program within the Maryland Technology Enterprise Institute (Mtech). It was established in 1987 with the goal of creating partnerships that help Maryland companies develop new products in collaboration with faculty at Maryland Universities. Funding is provided for research at the host University, and requires a significant matching commitment from the company partner, dependent on the size of the company. MIPS has demonstrated concrete economic benefits to the state of Maryland in the form of jobs, company revenues and associated state and county tax revenues[45].

The projects supported by MIPS span the commercial space from proof of concept through early commercialization and prototype development. Over five years (CY 2013-2017), on average 35% of MIPS project funding has been awarded to clean energy technology projects. This corresponds to an average of $0.54M/yr for early commercialization and $0.54M/yr for proof of concept projects.

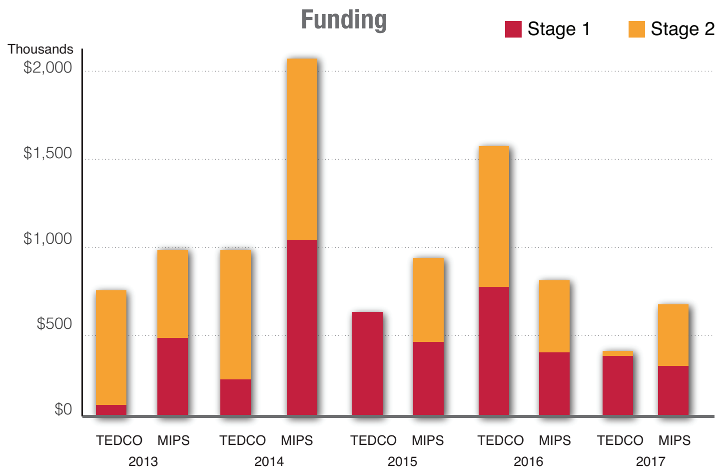


Figure II-4: Annual clean energy innovation spending from TEDCO and MIPS from 2013-2017. MIPS funding is available only for University-based projects. The levels of funding are highly variable from year-to-year because the TEDCO and MIPS programs do not have a specific mandate to support clean energy innovations.

II.A.2 Support for Early Development and Market Growth

Programs supported under the Strategic Energy Investment Fund (stages 3 and 4)

The Strategic Energy Investment Fund, established in 2008, has the broad purpose of decreasing energy demand and increasing energy supply to promote affordable, reliable, and clean energy to fuel Maryland's future prosperity. The Strategic Energy Investment Fund is supported primarily from auction revenues of the Regional Greenhous Gas Initiative (RGGI), with additional inputs from RPS alternative compliance payments, and other payments to the state related to energy, such as settlements related to PSC issues. Its present authorization specifies its distribution of funding:

- At least 50% for energy (bill) assistance;
- At least 20% for energy efficiency, with at least one half of that for low and moderate-income energy efficiency and conservation;
- At least 20% for renewable and clean energy programs, energy-related education and outreach, climate change and resiliency programs, and
- Up to 10%, but no more than $5M for administration.

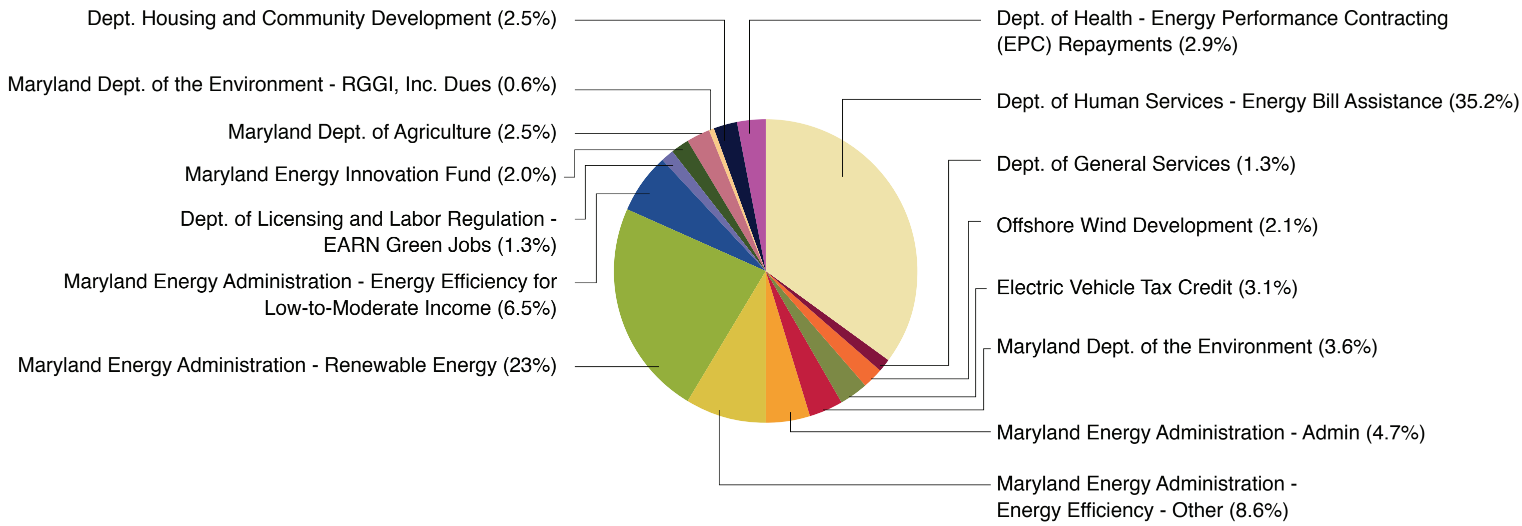


Figure II-5: Distribution of SEIF revenues in FY2018. Total reported expenditures from programs under the SEIF were $76.8 M. The chart is adapted from the FY2018 SEIF report.

As illustrated in Fig. II-5, many different agencies are responsible for delivering programs that are funded through the SEIF. The total program expenditures have averaged $86.4M/yr over the past 5 reporting years. Of that, we assess that on average $46.4M/yr (54%) has been used for projects that advance deployment of clean new energy technologies. Our agency-by-agency assessment is presented in Appendix A.2, and the summary of the agency breakdown is shown in Fig. II-6.

The Maryland Energy Administration supports the largest share of SEIF-funded clean energy programs that would fall within the Maryland Clean Energy Innovation System, with additional significant programs in the Maryland Department of the Environment, the Maryland Department of Housing and Community Development, and the Maryland Department of Transportation. Of the SEIF–supported programs that would not compose part of the Maryland Clean Energy Innovation System, the largest is the Maryland Department of Human Services program to provide electric utility payment assistance to eligible low-income households.

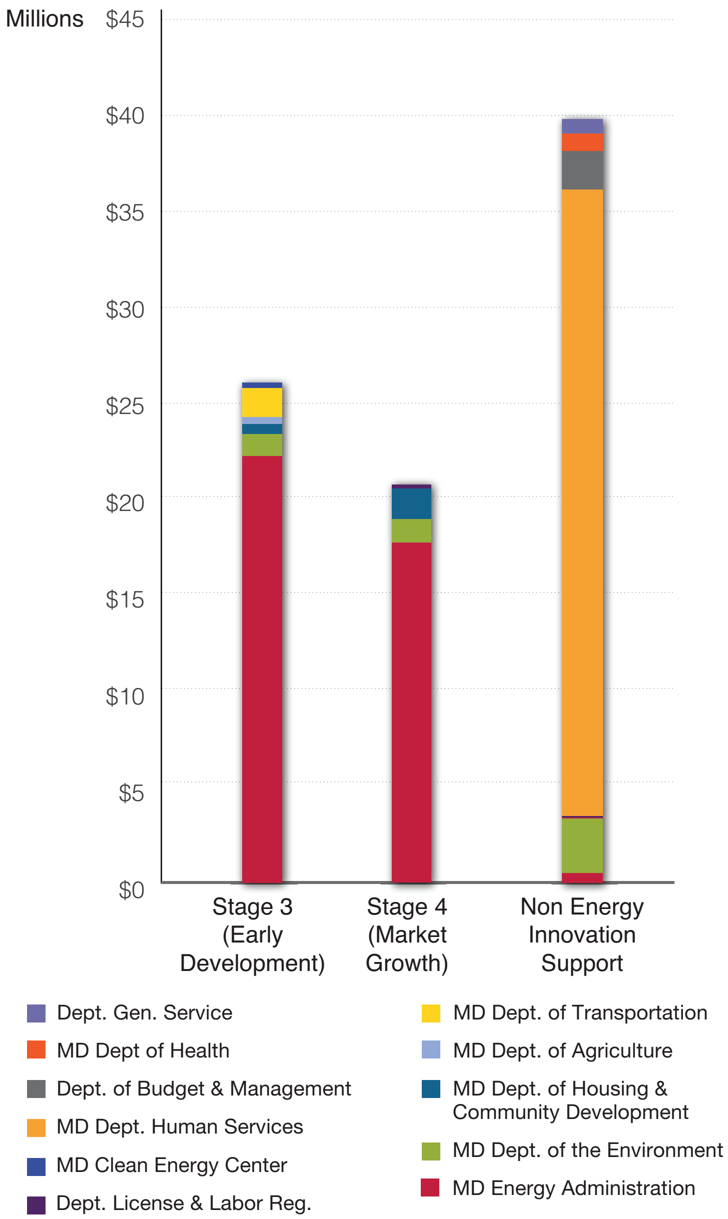


Figure II-6: Average Annual Spending by programs under the SEIF in the context of the stages of clean energy innovation. Total average spending was $86.3M/yr, of which $26M/yr supports early deployment of emerging technologies (category 3), and $21M/yr supports market growth for established technologies (category 4). About $40M/yr is used for other purposes that do not contribute to expanded deployment of clean energy technologies.

Programs Supported Under Maryland EmPOWER (Stage 4)

Maryland's largest expenditures related to clean energy technology are carried out through the EmPOWER Energy Efficiency program. EmPOWER was established in 2008 to help Maryland's citizens access products and programs that reduce their energy costs and improve their quality of life. The EmPOWER Energy Efficiency and Conservation (EE&C) programs incentivize the purchase and use of efficient appliances, HVAC systems, lighting, and building efficiency, etc. As such they increase commercial deployment of more effective clean energy technologies, although EmPOWER's authorization does not include a focus on products manufactured in-state. Over the past 5 reporting years (calendar years 2013-17), Maryland EmPOWER average annual program spending was $319M/yr, of which we assess the amount relevant to expanded deployment of clean energy technologies was $248M/yr, all in the market growth category.

Even though EmPOWER's programs were not established for the purpose of increasing deployment of products produced in Maryland, they can impact employment in the state in areas other than manufacturing. In particular, the installation and service requirements of many of the energy efficiency products incentivized under the EmPOWER EE&C programs likely contribute to Maryland's strong employment figures in building efficiency (Figure II-7). Consistent with the lack of focus on in-state products, the employment types in the buildings sector have a smaller percentage of manufacturing jobs than would be expected based on US averages.

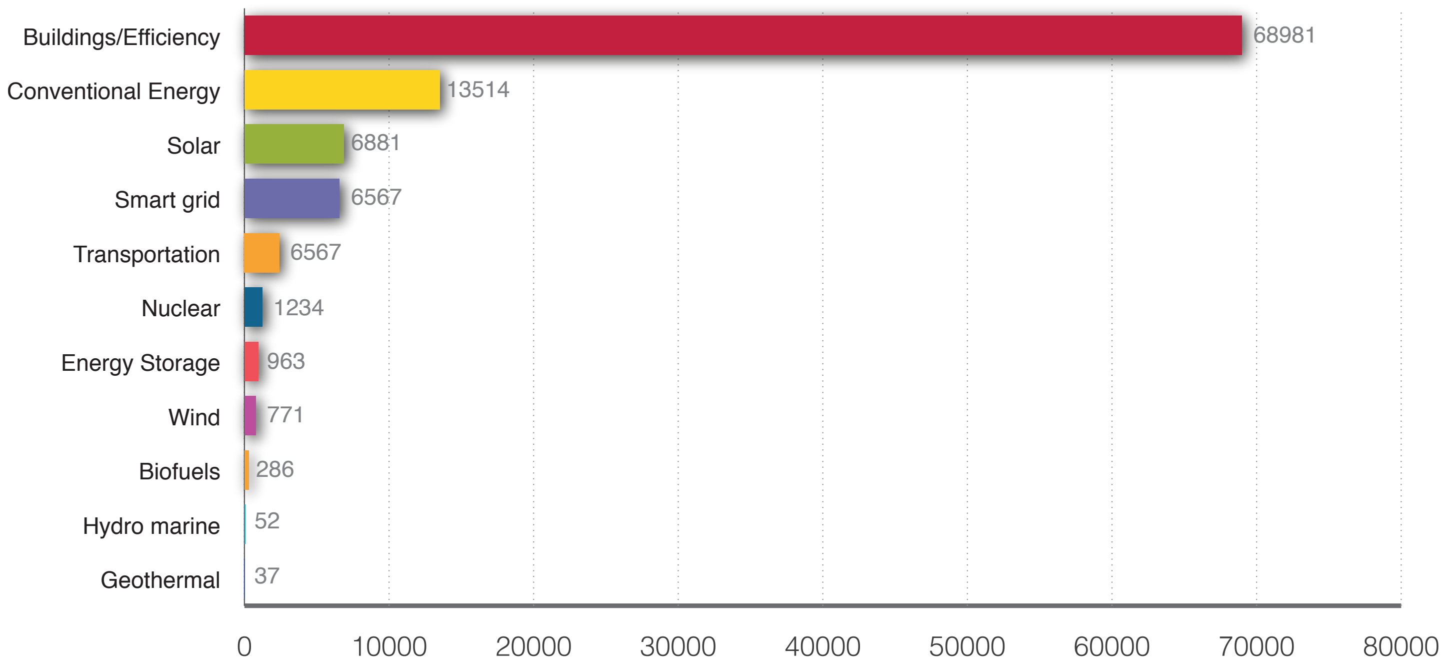


FIGURE II-7: **Maryland has 101,710 people (16 people per thousand population) employed in energy. Of these energy jobs, clean tech jobs represent approximately 86% of the total, with the remainder in the "conventional energy" category. Of the jobs in the dominant Buildings Efficiency category, 74% are in construction/installation and 4% are in manufacturing, compared with 58% and 14% respectively in the US overall.[46]**

EmPOWER programs also certainly play a role in Maryland's strong state ranking (7th among all the states) in energy efficiency[47] (figure I-8), has recently improved significantly. The ACEEE assessment states "Maryland Utilities in the state have steadily ramped up efficiency programs in recent years, spurred by strong energy reduction goals established by the state's Public Service Commission (PSC) in 2015 (and codified in 2017) to reach 2% annual savings. To date, these efforts, delivered through the EmPOWER Maryland Program, have saved more than 8 million MWh, with expected savings of approximately $9 billion over the life of installed measures."

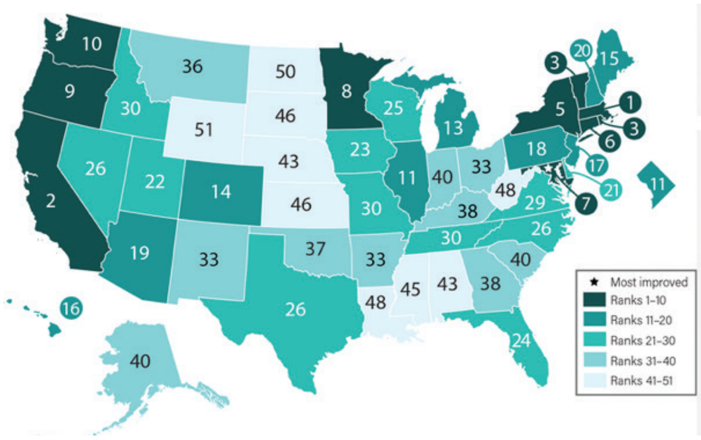


Figure II-8: From 2019 ACEEE report. Cumulative state rankings in energy efficiency, showing Maryland ranks 7th among US states.

II.A.3 Department of Commerce (DOC)

The Department of Commerce promotes economic development in the state, and thus provides a spectrum of business services. The DOC's largest expenditures are for financing and training. The Agribusiness and Energy Program, which is within the Business and Industry Sector Development Division, includes clean energy businesses. The amount of support provided for clean energy technologies is not called-out individually in DOC's reporting.

DOC manages the application process for two investment tax credit programs. The Biotechnology Investment Incentive Tax Credit (BIITC, created in 2005)[48] and the Cybersecurity Investment Incentive Tax Credit (CIITC, created in 2013)[49] are intended to help attract equity capital to Qualified Maryland Biotechnology and Cybersecurity Companies. The two tax credit programs provide credits to qualified individuals or entities that invest at least $25,000 in a small Maryland company (with less than 50 employees) certified by DOC and that files an income tax return in a Maryland county. Since 2015, Maryland has capped the annual allocation for BIITC at $12 million and CIITC to $2 million.

As defined, these programs could potentially benefit a subset of clean technology firms. For example, a young bio-energy company or a company developing cybersecurity services for clean energy products ostensibly could utilized the BIITC or the CIITC respectively. However, the majority of clean energy firms are not eligible for assistance in attracting investors through these funds.

Either or both of these funds might be considered as a basis for introducing investment incentives for clean energy firms. As of September 2019, the BIITC is oversubscribed (more than 200 companies applied and are in the queue for pre-qualification since DOC began accepting applications for FY2020 in June), suggesting that there is healthy investment in biotech even with an uncertain tax incentive. Meanwhile, since DOC began accepting applications for FY2020 last June through early September 2019, no companies had applied for the CIITC, suggesting funds may be available for other uses.

DOC's financial reporting structure has not shown itemized expenditures for clean energy technologies, although there are opportunities that could be used by clean energy firms,[50,51] so we do not include DOC support as a present component of funding for Maryland's Clean Energy Innovation System. For comparisons with other states (section III) we assess clean energy innovation funding by including states' reported loans and tax credit expenditures only if they are explicitly and quantitatively assigned to clean energy technologies.

II.A.4 Summary of the Maryland Funding for its Clean Energy Investment System

The funding elements outlined in the previous sub-sections, and presented in Appendix A2, are summarized in Figure II-9. By far the largest financial commitment is for market growth of commercially proven technologies, with most of the funds provided by the EmPOWER program under its legislatively mandated goals for energy efficiency in use of electrical power and natural gas. The large allocation of funds does not target the growth of in-state firms working on development and deployment of new clean energy technologies.

The amount committed to supporting the early deployment of emerging technologies, such as off-shore-wind and energy storage, is more than ten times smaller than

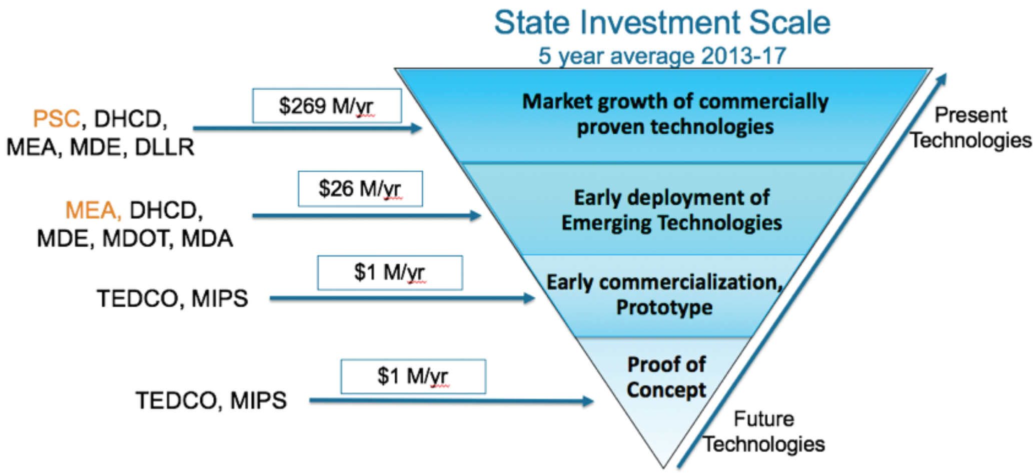


FIGURE II-9: State Spending in the different stages of Maryland's Clean Energy Innovation System: The spending numbers shown are 5-year averages over 2013-17. In the top (market growth) category, funding overseen by the Public Service Commission (PSC), provides by far the largest component, and in the 'early deployment of emerging technologies' category MEA provides the largest component. The values for the clean energy technology support from MIPS and TEDCO were provided by those agencies. MIPS funding is available only for University -related projects.

that for market growth, and also does not target in-state development and deployment. MEA has the largest programs supporting early deployment of emerging clean energy technologies. The Maryland Clean Energy Center (MCEC) is exploring the use of innovative financing activities to support technology commercialization at the 'early deployment' stage.

Prior to the authorization of MEI[2], there were no dedicated state programs for the earliest stages of clean energy technology (proof of concept and early commercialization). However, the MIPS program has included many clean energy projects in its portfolio, and TEDCO has supported some. Support for these two stages of commercialization together has been less than 1% of total spending in Maryland's overall Clean Energy Innovation System.

II.B: Status of Maryland's Clean Energy Innovation System

A key goal for Maryland's Clean Energy Innovation System is delivering the economic benefits of early-stage clean energy companies that remain in Maryland and grow their operations here. Coordination among programs operating at the different stages of commercialization – a coordinated State Clean Energy Innovation System - is required to achieve this. However, the activities illustrated in each stage of Fig. II-9 were not designed with the integrated goal of creating or supporting a pathway for in-state commercialization of clean energy. Instead, they operate largely independently, delivering valuable programs but without coordination and defined goals to support the growth of in-state clean energy firms that develop and deploy new technologies.

II.B.1 Stage 3 to 4 Transition: Moving from Early Technology Deployment to Market Growth

Expenditures for market growth, stage 4 in the commercialization pathway, are primarily provided through EmPOWER. Its programs are conservatively designed, with the intent of insuring clear benefits to the state's utility customers[52]. It is possible that some part of support for mature energy efficient products may now be better served by state-guaranteed loans,[53] but doing so would require legislative authorization. If authorized, this could maintain existing benefits while freeing up funds to develop new approaches to delivering increased value to customers based on emerging technical opportunities, such as energy storage coupled with renewable power.[54] It is also the case that uptake of more energy efficient products, while still valuable, will not deliver the same energy efficiency gains as in the past. This is because due to past program successes, in the future there will be fewer and fewer of the old inefficient products to be displaced. The present EmPOWER goals of reducing electricity consumption year-by-year will be in place through 2023, but new legislation for 2024 could adjust the program's goals to have a broader remit in line with Maryland's new RPS standards. An effective adjustment could include goals in reduction of greenhouse gas emissions, and in increased deployment of emerging technologies such as energy storage, electric vehicle charging, effective electrification, etc. On such topics, EmPOWER could, for instance, work with MEA in preparing emerging technologies for greater deployment.

MEA's Game Changers program (2013-16), is an example that could be used in expanding support for stage 3 technologies. The Game Changers program focused on both driving economic development opportunities and providing consumer benefits from innovative technologies, primarily in renewable energy deployment. Funding opportunities included innovative technologies with the potential to reduce the cost or increase the efficiency of Tier 1 renewable energy systems, and integration of energy storage systems with a customer's renewable energy source. Expanding MEA's effort in such areas apparently would require legislative modification of the requirements for use of the SEIF.

Programs that focus on technologies in the early-deployment stage offer long-term economic benefits that will grow and deliver sustained value. Maryland's present ratio of support for early deployment compared with market growth should be increased to develop these opportunities. Coordinated programs between MEA and EmPOWER would be one approach to accomplish this. In addition, more stage 3 (early deployment) support is needed for young companies that are moving from early commercialization into their first stages of deployment. Examples of the types of programs to support this transition include stage 2 infrastructure for scale up and field testing, and stage 3 programs for early demonstrations. Coordinated programs among MEA, MEI^2, MCEC, TEDCO and University venture programs could meet this need.

II.B.2 Stages 1 and 2: From Proof of Concept, through Early Commercialization

Experience in creating successful outcomes for commercialization of clean energy innovation indicates that both *developmental support* and *seed funding* play an important role[55,56]. Key issues that must be addressed in clean energy innovation, are that 1) the products require science and engineering development that takes time, 2) the early-stage companies are often competing for a market already occupied with incumbent products, and 3) scale up and product demonstration are generally required before early stage companies can capture market share. The pathway to commercializing clean energy technologies is thus intrinsically different that the traditional venture capital approaches used for software and some medical advances[57]. However, successful approaches for accelerating the early stages of clean energy innovation have been developed and demonstrated (e.g. SDTC, ARPA-E, Cyclotron Road, CEVG)[58]. Key factors for early-stage companies include developmental support such as:

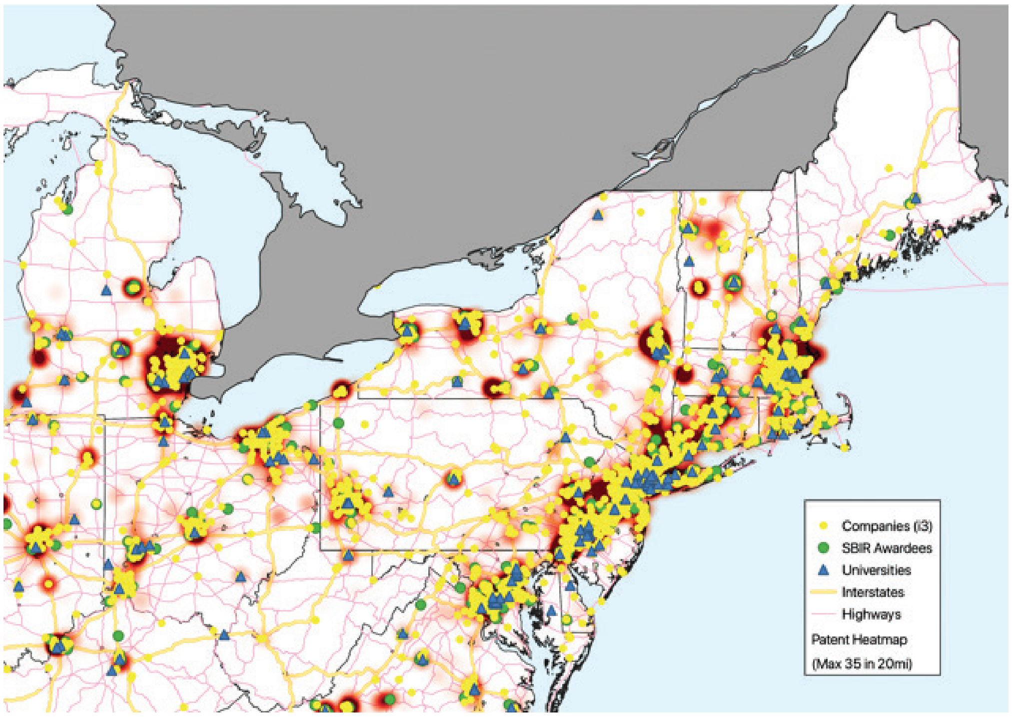
- Training and Mentoring for business issues essential to commercialization
- Space (incubator) and seed funding
- Technical mentoring with development milestones
- Networking to develop supply chains, early markets and investment opportunities
- Networking and incentives for partnerships with established businesses
- Guidance in accessing federal, state and local incentives and private funding opportunities

As we will show in Section III, providing such developmental support is an important component of the greater success some of our 'comparison states' have had in clean energy innovation. Maryland has some excellent programs providing such developmental support with a focus on biotechnology. These include the Maryland Technology Enterprise Institute (MTECH), and TEDCO's new state-wide Incubator Assistance Program and SBIR/STTR proposal lab. This provides a basis that can be leveraged to provide developmental support for clean energy technologies as well. With the new developments in TEDCO's strategic planning[59], there will be significant opportunities for program coordination among MEI^2, MIPS and TEDCO as described in in section IV.

Maryland's seed funding for clean energy innovation combined for stages 1 and 2 has averaged $2M/yr over the past 5 years. We present an assessment of how that compares with peer competitor states in Section III, with a recommendation to place Maryland at a midpoint of the other states' per capita seed funding levels.

Clean Energy Innovation Indicators

Many indicators of clean energy innovation represent the cumulative impact of investments over the previous 10-20 years. These include patents, Federal Small Business Innovative Research (SBIR) awards, and the formation of clean energy firms. The two maps below show clusters of clean energy innovation in locations with strong business drivers (e.g. Detroit, MI or Westchester, NY) and along the Northeast corridor, with additional clusters often near a University or government laboratory. Maryland's performance in the cumulative patent, SBIR and firms indicators are close to the average of all 50 states, but lower than the performance of other states that have innovation ranking similar to Maryland's.



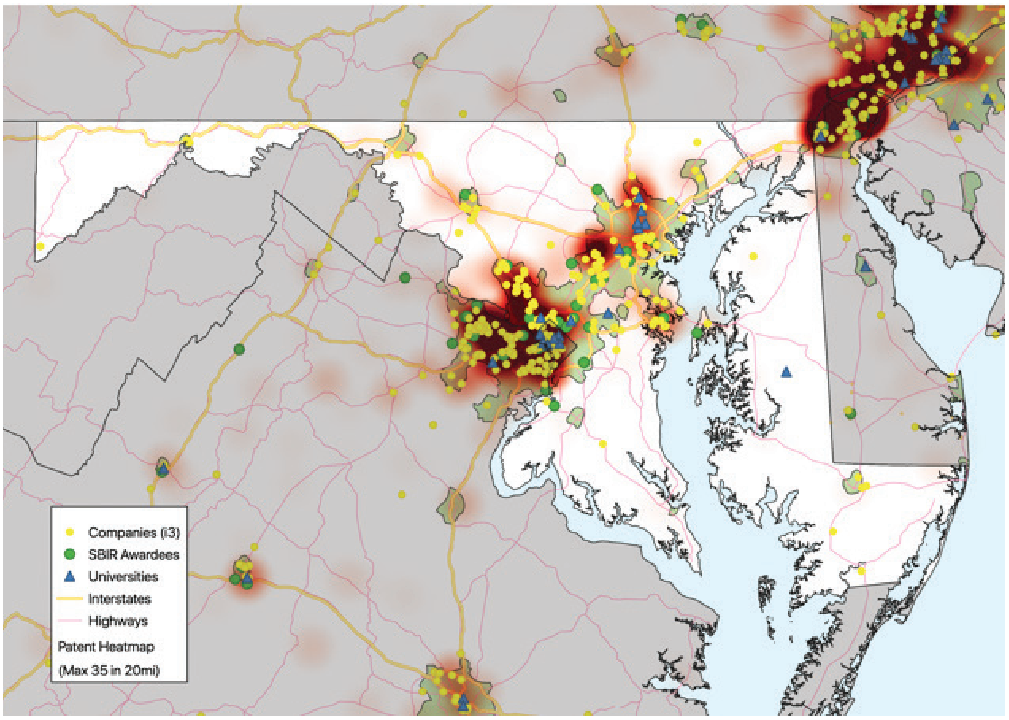


FIGURE II-10: **Distribution of universities, patents, SBIR awards and cleantech firms in northeastern states, and an expanded view for Maryland. Patent numbers and SBIR awards are cumulative over 2007-16 and 2008-17 respectively.**

II.B.3 Maryland's Clean Energy Innovation System

As discussed in the introduction, Maryland's narrow focus on biotechnology innovation has left little room for economic development based on innovation in other technology areas, including clean energy. While Maryland does support significant programs related to clean energy, these programs were largely *not* designed to support in-state development and deployment of clean energy technologies for economic development. As a result, the programs have different mandates and are not coordinated for to meet energy innovation goals. The majority of the later stage programs do not prioritize support of Maryland companies. As a result, the system presently does not function to deliver the potential economic benefits of a state clean energy innovation system.

However, the basis of clean energy expertise represented in Maryland's present energy programs, along with the state's strength in innovation provide clear opportunities to alter this assessment.

II.C The Health and Potential of Maryland's Clean Energy Innovation Firms

In the past decades Maryland has seen a core of early-stage clean energy commercialization activities – both young companies and new ideas emerging from the state's universities – emerging and taking advantage of new DOE funding structures designed to encourage commercialization of innovative concepts. This trend indicates an emerging potential for growth and economic impact of in-state clean energy firms, that will grow if supported. As discussed in the introduction, the state has historically not placed a strategic focus on the economic opportunities of clean energy innovation. However, Maryland has strengths that can be readily leveraged to exploit the new opportunities in clean energy innovation.

As shown in the map in the textbox (Fig. II-10), Maryland's clean energy innovation firms are clustered near the R&D hubs of the state around several Federal facilities, state university campuses, and also distributed across the state from Garrett to Worcester Counties. Among these firms there is a growing number that have taken advantage of new types of Federal support designed to accelerate commercialization of innovative clean energy technologies.

The distribution of technology areas being addressed by Maryland's growing population of clean energy firms is shown in Figure II-11. The distribution shown is similar to the US average, and includes a broad set of approaches to clean energy innovation as discussed in Section I.C.

In addition to the energy-related SBIR awards shown in Fig. II-10, Maryland universities and companies are also awarded substantial other energy related funding from the Department of Energy (DOE) for both early stage R&D[60] and for later-stage development[61], as shown in Figure II-12, on the following page.

The distribution of programs supported by DOE includes fundamental research topics (supported by the Office of Science) of the sort that may lead to an innovation. The applied energy offices, Energy Efficiency and Renewable Energy (EERE), Electricity Delivery (OE), Nuclear Energy (NE) and Fossil Energy (FE), support research and development. Support from these offices can help

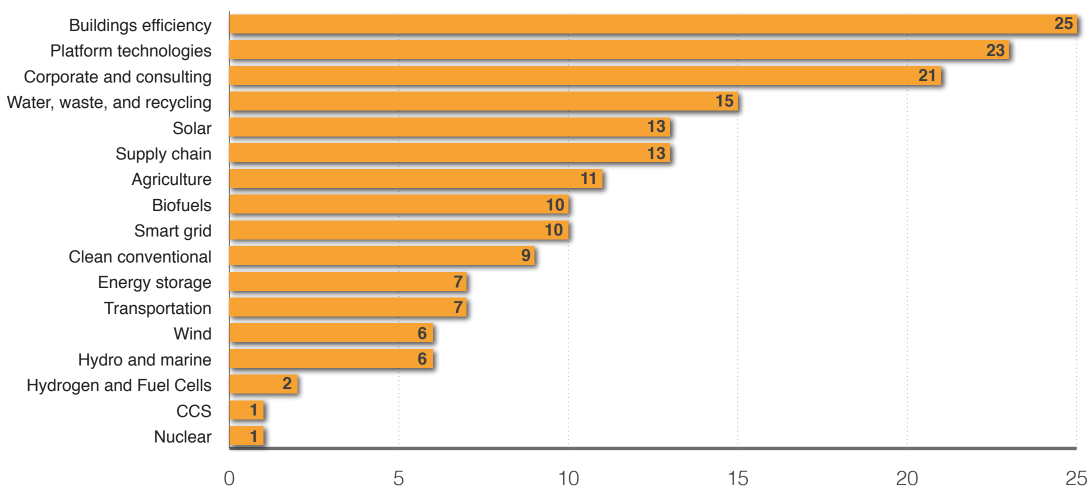


Figure II-11: Maryland's clean energy firms broken down by technology focus. The base data from I3 (used for 50 states comparisons) has been expanded for MD using additional databases (see Appendix D) and consultation with clean energy networks in the state. The expanded list captures companies in the earliest stage of development.

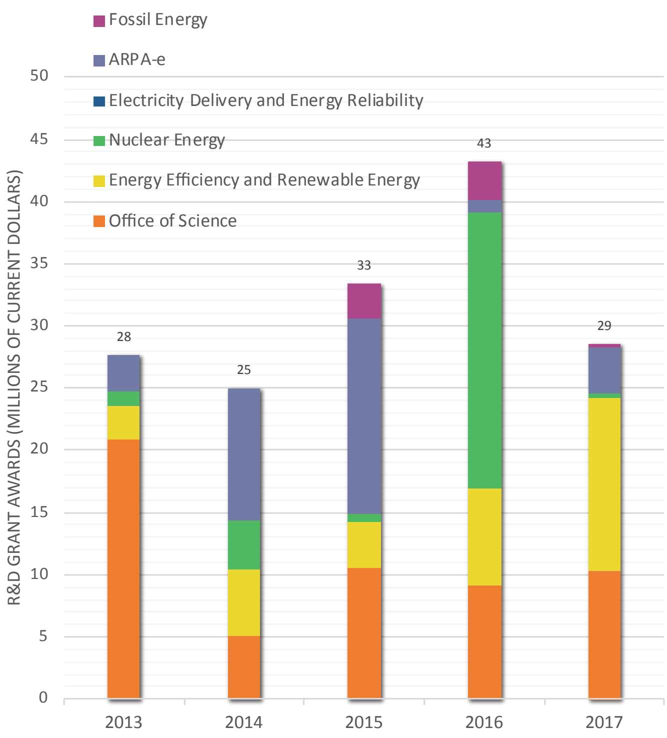


Figure II-12: Department of Energy R&D Funding in Maryland, 2013-17.

advance proof of concept or prototype development. The Advanced Research Projects Agency – Energy (ARPA-E) was established in 2010 with the specific goal of accelerating the development of clean energy innovations, with a focus on economic impact via commercialization of the most promising new technologies. University teams and small companies that receive ARPA-E awards work under a program of technical and commercial milestones designed to prepare them to attract private sector investment at the end of three years of ARPA-E support.

Research teams from Maryland, supported by programs of technology innovation and entrepreneurship at Maryland's Universities, have been successful in competing for and performing under ARPA-E support (see Appendix C for the list of 22 projects funded from 2010 to 2019 to date). Between 2010 and 2017, 19 Maryland projects were awarded a total of $20.8M, placing Maryland 14th among all states in the amount of funding and 12th (or 10th if repeat performers such as DOE National Laboratories are omitted) in the number of awards.

We assess the ARPA-E results as a leading indicator of emerging strength in Maryland for in-state commercial development of clean energy innovations. Based on interviews and stakeholder discussions (see Appendix F), we attribute this emerging strength to: investments by the state's universities in technology innovation and entrepreneurship and in some cases to energy innovation in particular; to Maryland's strong technical workforce; and to the commitment of individual scientists and engineers to developing solutions to the negative consequences of greenhouse gas emissions.

This emerging strength represents a moment of opportunity for the state to combine its societal goals for clean energy and efficiency with expanded economic opportunities through in-state clean tech development.

Maryland's indicators for success in clean energy innovation are summarized in Table II-1. We see that the lagging indicators – patents, SBIR grants and number of clean tech firms per capita – place Maryland's ranking

Category	Innovation Score ITIF - New State Economy 2017	Overall R&D funding 2016, per capita	DOE R&D Funding annual average, 2013-2017 Per capita	Energy related patents 2007-2016 Per capita	Energy-related SBIR funding, 2008-17 Per capita	Clean energy companies Per capita	# ARPA-E awards 2010-2017
Ranking among 50 states	**6th**	**2nd**	**21st**	**33rd**	**22nd**	**25th**	**10th**

TABLE II-1: Summary: Maryland rankings in energy innovation indicators and outcomes. Color codes indicate overall innovation capability (green), lagging indicators (yellow) and leading indicators (red).

in the mid-range among states, lower than would be expected based on its innovation and R&D strengths. We will address the tactical reasons for this in more detail in Section III, but an underpinning driver is that the state of Maryland has made strategic decisions not to prioritize energy R&D, as described in Section I and illustrated in Figure 1-4. The leading indicators of emerging potential for clean energy innovation in Maryland are the quantitative results for ARPA-E support, and qualitative assessments of recent entrepreneurial clean tech activity in Maryland, such as illustrated in the textbox in Section I.C.

The quality of MEI² seed funding recipients (Appendix C), and Maryland's ranking in ARPA-E awards, indicate a growing opportunity for economic development in Maryland based on clean energy innovation.

II.D Summary of Key Findings

Findings concerning the availability and efficiency of the use of funds for the development and deployment of clean energy technology in the State and the commercialization of that technology include:

1. Maryland has spent $400M/yr on average over the last 5 years on its EmPOWER utilities programs and Strategic Energy Investment Fund, none of which is authorized to support commercial development of in-state clean energy technologies. Support from other state sources for commercial development by innovative in-state clean energy firms has averaged only $2M/yr .
2. Maryland's strong social commitments to the consumer benefits of energy efficiency are demonstrated financially through the support for clean energy technologies provided by the EmPOWER program and programs supported under the SEIF. However, these programs are not authorized to support the growth of innovative clean energy firms that will develop and produce their products in state.
3. The energy programs supported under EmPOWER and the SEIF have created a basis of clean energy expertise in Maryland that could be coordinated under expanded state goals to support in-state firms that develop and manufacture clean energy technologies.
4. Before the establishment of the Maryland Energy Innovation Institute (MEI²), Maryland had no dedicated programs to support early stage development and commercialization of clean energy technology. In the two years since it was established, MEI² has demonstrated the opportunities that a relatively modest amount of funding can provide in terms of developmental support and seed funding for innovative clean energy firms.
5. Neither the Department of Commerce nor TEDCO have had specific programs to support clean energy innovation, although both have programs in which clean energy firms could participate. Maryland's clean energy innovation system has the potential to enable much more effective outcomes if state goals were set for well-designed support coordinated among DOC, MEA, MEI² & MCEC, TEDCO and University venture programs.
6. Data on the clean energy firms in the state and their activity shows that over the past decade there has been some notable clean energy activity leading to the formation of promising young firms in the state. This trend has occurred in part due to increased university support for innovation and entrepreneurship and demonstrates an emerging potential for growth and economic impact of in-state clean energy firms.

The high-level conclusions of the assessment are:

At present Maryland has many of the components necessary for a successful Clean Energy Innovation System, but it lacks strategic focus, support, and coordination.

In the following section (Section IV) we will build on our understanding of the present status of clean energy innovation and commercialization in Maryland to evaluate what is needed to derive greater state economic benefits. To do so, we will consider the structure and funding of clean energy innovation systems in other states that have innovation strength similar to Maryland's.

SECTION III

Forecast need for funds for clean energy development, deployment and commercialization

In the Introduction and Section II, we have shown that while Maryland has strong societal commitments to energy efficiency and clean energy and a very strong research infrastructure, the state has failed to take full advantage of the economic development opportunities that innovative young clean-tech companies can provide the state. In this section, we will forecast the type of programs and amounts of funding needed to structure the state's clean energy innovation system to deliver in-state clean energy development, commercialization and deployment. We will also demonstrate methods of assessing progress in clean energy innovation, which will also serve as metrics that to evaluate future progress in improving Maryland's energy innovation system.

States	ITIF Innovation Potential: State Ranking	Number of Clean Energy Companies Per Million People*
MD	6th	16
CO	7th	51
NY	11th	26
CT	10th	32

TABLE III-1: Innovation scores and number of clean energy companies per million people) for Maryland and the comparison states. (firms comparison based on I3 database).

To create our forecast of needs, we used comparisons with other states to assess what approaches are most useful for creating positive outcomes. For the comparison, we selected three other states with similar or lower innovation metrics, New York, Connecticut and Colorado, but stronger outcomes in development of clean energy firms, as shown in Table III-1 (see also Section I, Fig. I-4). The results of these comparisons show that there are practical actions that will deliver the economic benefits of a healthy population of in-state clean energy companies for Maryland.

In addition to the state comparisons, we also carried out a detailed assessment of Maryland's present clean energy firms, both clarifying the firms listed in the standard data base, and identifying a significant number of additional firms that were not listed. For this extended base of firms, we developed assessments of the firms' health and productivity, and carried out a comparison with firms in one of the comparison states, Colorado. These assessments provide the basis for our funding recommendations, which are presented in Section IV.

III.A Comparisons Among Maryland, Colorado, New York and Connecticut

The states chosen for comparison with Maryland have similar innovation rankings, and clear policy commitments to clean energy, but very different clean energy characteristics, as summarized in Table III-2. All have good efficiency rankings, with MD, NY and CT in the top ten ranked states. CO, MD and CT have similar clean energy employment figures (state rankings 12-20) while NY's clean energy employment is significantly lower (state ranking 38). They also vary in their in-state production of renewable energy – Connecticut has included almost no renewable power in new building of

States	Population 2018	ACEE Efficiency Ranking 2019	Clean Energy Employment (jobs per thousand people)	In-state Renewable Power Generation (% of all capacity)	Renewable Share of New-Build Power 2008-17	CO_2 Emissions Reductions Since 2005
MD	6,042,718	7th	14	828 GWh (0.7%)	26.3%	30.6%
CO	5,695,564	14th	12	10,269 GWh (6.6%)	49.7%	7.5%
CT	3,572,665	6th	12	53 GWh (0.1%)	2.2%	23.0%
NY	19,542,209	5th	9	4,318 GWh (3.4%)	45.0%	22.7%

TABLE III-2: Comparison of state metrics relevant to clean energy deployment.

electric power, and its overall renewable generation is only 0.1% of its total generation capacity. CO and NY's new power builds include almost 50% renewables and their renewable power generation amounts are 6.6% and 3.4% of their total generation capacities respectively. Despite its strong deployment of renewable power, Colorado's emissions reductions are markedly weaker than the other three states'.

The four states also have different approaches and outcomes in implementing in-state programs related to developing and deploying innovative clean energy technologies. A description of Maryland's policies is presented in Section I and its programs related to energy technologies are presented in Section II. For comparison, a brief introduction to each of the comparison states is provided in the text box "Overview of Comparison States". A more detailed review is presented in Appendix E.2.

The metrics for clean energy innovation introduced for Maryland in Section II, are shown in Table III-3 for the comparison states. As in Section II, the first two columns (Innovation Potential, Overall R&D funding) indicate the capability to discover and develop innovation new energy technologies. The next four categories (DOE grant funding, clean tech patents, Energy-SBIR funding, and # of clean-tech companies) provide a time-integrated history of clean tech innovation and commercialization activities. The last column, ARPA-E awards, is a leading indicator of clean energy entrepreneurship, as discussed in Section II.C.

As with the overall clean energy metrics shown in Table III-2, there is considerable variability among the states in the innovation metrics of Table III-3. Maryland has extremely strong standing in the indicators of capability shown in the first two columns. CO is consistently strong in all remaining indicators, New York and Connecticut are strong in some, while Maryland is overall lower in the lagging indicators, consistent with the state's historical lack of support for clean energy innovation as an economic development focus. However, Maryland has demonstrated stronger performance in a leading indicator of clean energy innovation, receipt of ARPA-E awards, than might have been suggested by its lagging indicators.

Overview of Comparison States

Connecticut has made substantial commitments to clean energy beginning with its 1998 electric restructuring legislation, when it established a Renewable Energy Investment Fund[62], which went through multiple reorganizations and diversions of funds in the following years. Prior to 2011, part of the fund was designated for the development as well as deployment of clean and renewable energy technologies. In 2011, the state re-designated these funds to establish the nation's first Greenbank, which provides loans at the market growth level (deployment only)[63]. Some funding for early stages of clean energy innovation is provided through Connecticut Innovations. Connecticut also makes substantial use of tax credits in supporting clean energy technical development and deployment for early deployment and market growth.

In the mid 1990's **New York** was one of the first states to enact laws to increase the use of renewable energy,[64] and in 2014 set ambitious goals to reduce greenhouse gas emissions by 80% by 2050. The state has established an integrated clean energy system, in which all stages from prototype to market expansion are supported under the New York State Energy Research and Development Authority (NYSERDA). The programs include both developmental support and direct financial support in the form of seed funds and grants. The state's programs are largely funded through utility surcharges and RGGI revenues. In addition, New York provides tax credits to support early deployment and market growth for clean technologies, and operates a Green Bank capitalized from utility surcharges.

Colorado has an industrial base in fossil fuels, a strong entrepreneurial culture, and a state-wide commitment to environmental quality. It established a renewable portfolio standard by state ballot in 2004. Colorado's utilities surcharge program, which supports market growth, is notably smaller than those of MD, CT and NY. The state uses incentives and sales and use tax exemptions to support early deployment of emerging technologies, and the Office of Economic Development and International Trade provides funding for early stage (prototype and early commercialization) of innovative clean energy technologies. Over seven years beginning in 2008, the state invested almost $8M in establishing a collaborative structure to support clean energy innovation, which engages its University system and benefits from the local expertise of the DOE National Renewable Energy Laboratory (NREL).

State Rankings	Innovation Potential (ITIF)	Overall R&D Funding, Per Capita	Per Capita DOE R&D Grant Funding	Clean Tech Patents Per Capita	Energy-Related SBIR Funding Per Capita	# Clean Tech Companies Per capita	# ARPA-E Awards** 2010–17
MD	6th	2nd	21st	33rd	22nd	25th	10th
CO	7th	18th	4th	7th	3rd	3rd	4th
NY	11th	23rd	20th	12th	20th	9th	3rd
CT	10th	6th	23rd	8th	6th	8th	15th

TABLE III-3: State rankings in Innovation: metrics of capability (1st three columns) for innovation, and indicators of activity in clean tech innovation, (last 4 columns). SBIR = Small Business Innovation Research, ARPA-E = Advanced Research Projects Agency-Energy. Color codes indicate overall innovation capability (green), lagging indicators (yellow) and leading indicators (red).

** To remove the effects of repeated awards to national labs and other large research centers, the ranking omits non-University performers with more than 4 repeat awards. Maryland ranks 12th if repeat awards are included in ranking all the states.

III.A.1 Direct State Financial Support for Clean Energy Commercialization

To assess the state financial commitments that give rise to more positive outcomes in clean energy innovation, we identified the funding focus and levels in the three comparisons using the same methods and definitions developed for the assessment of Maryland. The stages of commercialization defined in Section II and Appendix A and indicated in Fig. III-1 were used for the comparison states. The data sources used and description of the assessment methods are provided in Appendices B and D.

The absolute clean energy funding levels provided by each of the states are compared in Table III- 4. Maryland and Connecticut stand out as investing over 100 times as much in market development (stage 4) than in the two early stage categories (stages 1 and 2). MD also stands out as having a substantially larger ratio of stage 4 to stage 3 spending than any of the other states.

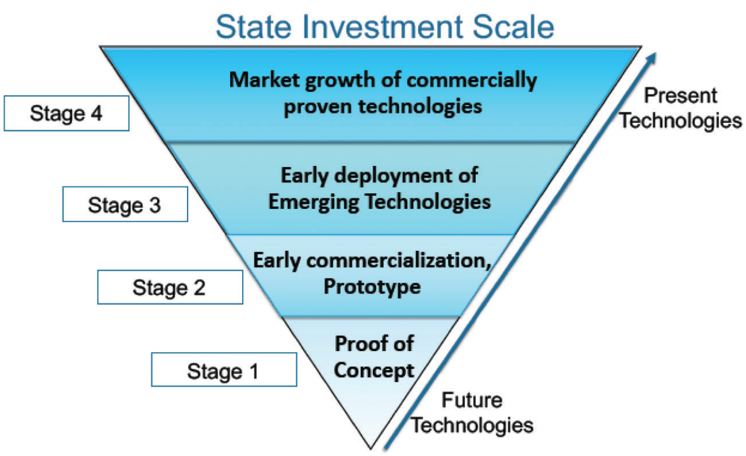


FIGURE III-1: Stages of innovation, development and commercialization

State	MD	CO	9 Rb	# H
Population (M)	6.04	5.70	19.54	3.57
Market Growth (stage 4)	$268M/yr	$70M/yr	$526M/yr	$201M/yr
Early Deployment (stage 3)	$26M/yr	$17M/yr	$119M/yr	$73M/yr
Early Commercialization (stage 2)	$0.96M/yr	$2.42M/yr	$8.20M/yr	$1.02M/yr
Proof of Concept (stage 1)	$1.04M/yr	$0.52M/yr	$12.9M/yr	$0.40M/yr
Total (stages 1-4)	**$296M/yr**	**$90M/yr**	**$666M/yr**	**$275M/yr**
Relative Spending: State 4 to Early Stage (1 & 2)	**134 to 1**	**24 to 1**	**25 to 1**	**141 to 1**
Relative Spending: Stage 4 to Stage 3	10.4 to 1	4.1 to 1	4.4 to 1	2.8 to 1

TABLE III-4: State population and average state funding per year ($M/y) in each of the four stages of commercialization, with the total for each state. Values represent assessment of spending in the commercialization stages of Fig. III as described in Appendix A, and do not represent all energy-related spending in any of the states.

* New York's Market Growth values represent new funds. Funds based on repayment of earlier loans are not included here (see Appendix E).

State	MD	CO	9 Rb	# H
Market Growth (stage 4)	$45/yr	$12.31/yr	$27/yr	$56/yr
Early Deployment (stage 3)	$4.31/yr	$2.91/yr	$6.07/yr	$20/yr
Early Commercialization (stage 2)	$0.16/yr	$0.43/yr	$0.42/yr	$0.29yr
Proof of Concept (stage 1)	$0.17/yr	$0.09/yr	$0.66/yr	$0.11yr
Early Stage Sum (Stage 1 + Stage 2)	**$0.33/yr**	**$0.52/yr**	**$1.08/yr**	**$0.40/yr**
Total Spending (all stages)	**$49.55/yr**	**$15.74/yr**	**$34.09/yr**	**$77.01yr**

TABLE III-5: Average per capita funding per year ($/y) in each of the four stages of commercialization. Second to last row, early stage innovation support = sum of Proof of Concept and Early Commercialization funding. Last row, total spending = the sum of stages 1-4.

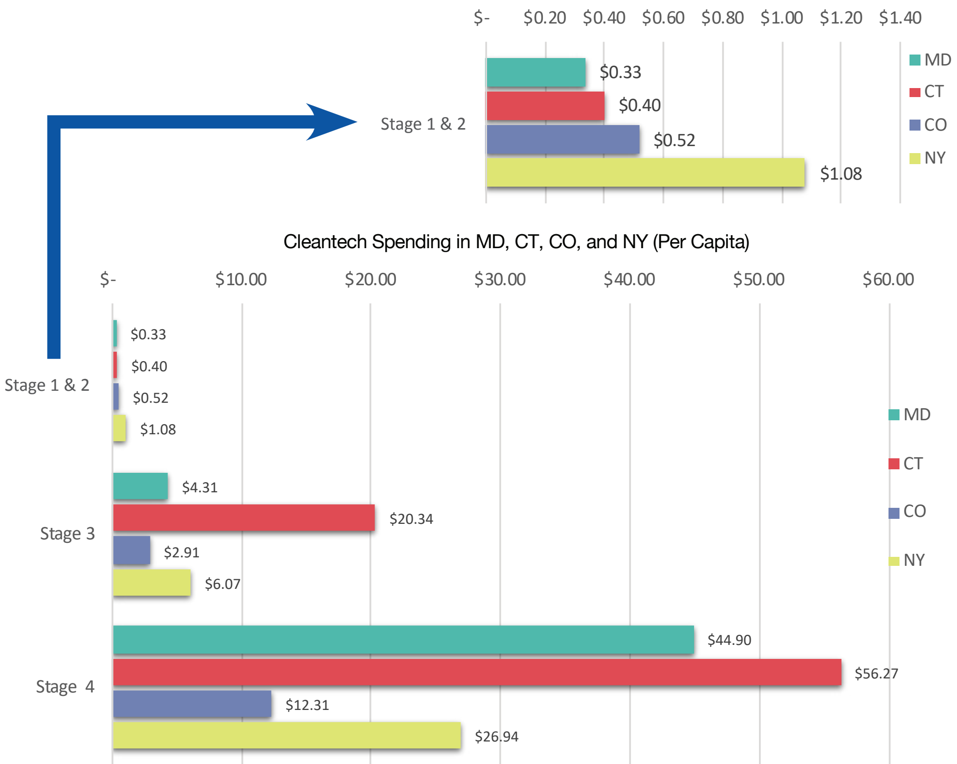


FIG. III-2: **Direct clean energy spending (per capita) relevant to commercialization in each of the comparison states, assessed as described in Appendices A, D and E. Stage 1 & 2 are early development (prototype development and early commercialization). Stages 3 & 4 are later stages of development (early deployment and market growth). Values are averages over several years of funding between 2013 and 2018 for each state. For Maryland the average is for 2013-2017. Values represent assessment of spending supporting the commercialization stages of Fig. III-1 as described in Appendix A, and do not represent all energy-related spending in any of the states.**

Direct comparisons among the states can be made based on the per capita values in Table III-5. Colorado spends the least per capita overall, primarily due to much lower funding from its utilities program which, as in the other states, supports stage 4 efforts. Maryland has the lowest per capita spending for early stage innovation (stages 1 & 2), Connecticut sends 1.25 times as much, Colorado 1.5 times as much and New York 3 times as much as Maryland on early stage innovation. The tabulated values are illustrated graphically in Fig. III-2.

The different states show different patterns of outcomes and spending – each related to the state's particular circumstances. Colorado is particularly interesting because, despite its low level of spending overall it has extremely strong activity indicators (DOE grants, patents, Energy SBIR awards, and number of firms per capita), as well ranking in the top five states in ARPA-E awards. Colorado's higher financial support in early stage innovation relative to Maryland is certainly a factor in its more positive outcomes.

Supplementing direct financial support, there are additional differentiating factors among the states (see Appendix E). The factor, in addition to direct spending, that appears most strongly linked to success in early stage innovation is state developmental support. This is described in the following section.

III.A.2 State Developmental Support for Clean Energy Commercialization

A key aspect in the success of clean energy innovation is early support in business development. All three of the comparison states provide developmental support targeted for clean energy innovation. As an example, Colorado's marked success in creating a dynamic clean energy innovation system has been accomplished with lower early stage innovation support than NY, and only moderately higher levels that MD and CT. Interviews with clean energy companies and other stakeholders in Colorado (See Appendix F) indicate that effective mentoring, networking and a robust entrepreneurial culture play a significant role in Colorado's energy innovation system. These factors are consistent with well-established principles of successful investment in energy investment[65,66].

Key issues that must be addressed in clean energy innovation, are that 1) the products require science and engineering development that takes time, 2) the early-stage companies are often competing for a market already occupied with incumbent products, and 3) scale up and product demonstration are generally required before early stage companies can capture market share. The pathway to commercializing clean energy technologies is thus intrinsically different that the traditional venture capital approaches used for software and some medical advances. However, successful approaches for accelerating the early stages of clean energy innovation have been developed and demonstrated (e.g. Sustainable Development Canada, ARPA-E, Cyclotron Road, Clean Energy Venture Group as described in reference 4). These developmental approaches are shown in parallel with the stages of direct financial support in the text box.

Developmental and Direct Financial Support in Clean Energy Innovation

Developmental Support	Financial Support
Mentoring in technical and business issues essential to commercialization	Seed funding for proof of concept
Space and support for product development and early scale-up for manufacturing (incubator support)	For 1st product development: state seed and investment funding state investment incentives
Networking to develop supply chains, early markets and investment opportunities	For 1st manufacturing and sales: state investment and small business incentives Demonstration and early deployment opportunities Risk-tolerant finance
Networking and incentives for partnerships with established businesses	Risk-tolerant finance and market incentives to support market growth
Guidance in accessing Federal, state and local incentives and funding opportunities	

Providing such developmental support in Maryland need not require large funding increases. Maryland has innovation-developmental opportunities such as incubators, networking and mentoring, but largely has prioritized the needs of the state's Biotechnology innovation focus in these programs. By expanding these existing state developmental support programs to include a specific focus on the opportunities of clean energy technologies, Maryland can provide its in-state clean energy innovation firms with the type of developmental support that has played a significant role in Colorado's positive outcomes. Some of the existing programs than can be expanded include University Venture programs (for instance, Johns Hopkins' Technology Ventures, and University of Maryland MTECH and UM Ventures), as well as new programs such as the Incubator Assistance Program SBIR/STTR proposal lab being offered through TEDCO.

III.B Metrics for Clean Energy Innovation Commercialization

The creation of a stronger clean energy innovation system in Maryland must be coupled with clear goals enforced by well-defined metrics to assess progress. The goals should be focused on the economic development opportunity of in-state firms engaged in developing, commercializing and deploying new clean energy products. Measuring progress will require tracking the number and productivity of the state's clean energy firms. Two important metrics are the rate at which young firms mature in commercial development and deployment, and the success of young firms in attracting the private sector investment needed for growth.[67]

Figure III-3 compares the rate of maturation of clean tech companies in Colorado and Maryland. The chart shows the number of firms founded in each year since 2000. Colorado has nearly three times as many clean tech firms in-state as Maryland, the result of an average rate of new company formation of 23 firms per year compared with 7 per year in Maryland. The added information on firm maturity provided in the chart is the present status of each company – whether it has closed, been acquired, reached maturity (including product sales) or whether it is still in product development. In Colorado, the fraction of firms still in the R&D/start-up phase of development (orange in the graphic) decreases steadily for older firms, while in Maryland a larger fractions of older firms are still in the R&D/start-up phase The Maryland companies also show a larger failure rate (24%) than the CO companies (14%), and a smaller acquisition rate (7%) than CO

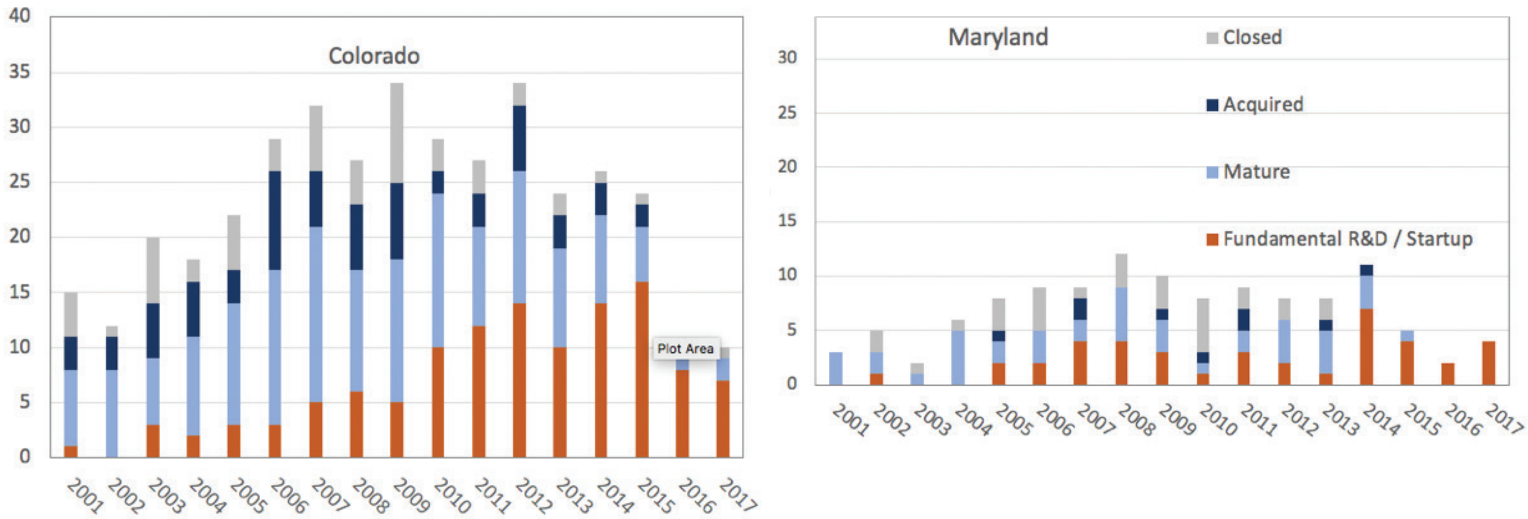


FIGURE III-3: Company health metric: The number of clean tech firms founded in Colorado (upper panel) and Maryland (lower panel) by year of founding. The color code indicates the *present* commercial status of the firms. Information shown is for the 119 MD firms and the 393 CO firms for which such data was available.

(17%). It is clear that Colorado's clean energy innovation system has been more effective in generating not only a larger, but also a healthier population of clean tech firms than Maryland's.

Another measure, an early-Investment success metric, is illustrated in Figure III-4. Information on private sector financing is not uniformly available, but we were able to obtain such information[68] for a subset of both Maryland and Colorado clean energy companies. The chart shows the number and amount of investments in terms of the number of years since a company was founded. Many companies receive more than one investment

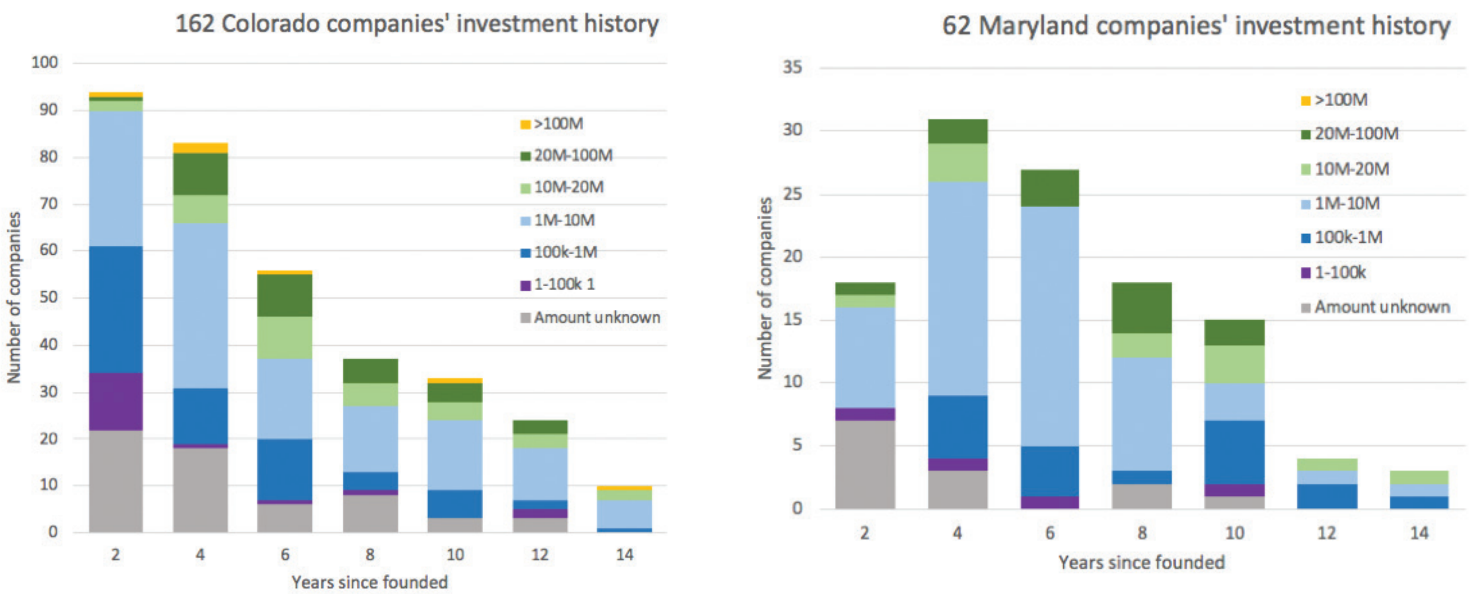


FIGURE III-4: Investment history of CO and MD clean tech firms relative to the year of their founding. Results are binned in two year intervals. The colors in the bars indicate how many firms raised private investment in each 2-year bin after funding at the levels indicated in the legend of the chart (e.g. purple in year 6 indicates 1-100k funding received in the 5th or 6th years after a company was founded). "Amount unknown" indicates that the company is known to have received funding, but the amount is not reported.

LEFT GRAPH: Investment information for 162 out of the 523 known firms in Colorado between 1999 and 2019.

RIGHT GRAPH: Investment information for 62 out of the 189 known firms in MD between 2002 and 2019.

and investments may occur a decade or more after the company is founded.

In both Colorado and Maryland, private sector investment has been much more productive in the last decade than in earlier years. For the 162 firms in Colorado for which information was available, the total reported amount of investment was $3.7 Bn, of which $3.1 Bn was raised by 109 firms between October 2009 and September 2019. For the 62 Maryland firms, the amount of investment was $0.90 Bn, of which $0.79 Bn was raised by 43 firms between October 2009 and September 2019. Overall, on a per firm basis, the Colorado firms have raised about 50% more in private investment than the Maryland firms, again indicating healthier as well as more numerous firms.

III.C Summary and Forecast Needs

Comparisons with other states that are similar to Maryland in innovation and R&D capability, and which also have strong social commitments to clean energy provide a basis for assessing the potential of what Maryland can accomplish in clean energy innovation and the pathways to do so. At present, despite its significant spending on energy efficiency and clean energy, Maryland lags the comparison states in clean energy patents, small business awards, and the number and health of innovative clean energy firms. The key factor in this difference is that Maryland has not had a strategic focus on clean energy innovation as an economic development activity.

Key observations from the comparisons with other states include

1. Maryland's per capita spending for early stage clean energy innovation, $0.33 per year, is the lowest among the comparison states (NY, CO and CT).

2. Maryland spends markedly less on early deployment of emerging technologies (stage 3) in comparison with its spending on deployment of mature technologies (stage 4).

3. The comparison states have had financial and developmental innovation support designated for clean energy innovation in place for 15 or more years, while Maryland has only initiated a small program of such focused support recently through the Maryland Energy Innovation Institute.

4. Maryland has existing innovation programs, now focused primarily on biotechnology, that can be expanded to provide the type of support needed for clean energy innovation.

5. Maryland has a solid core of innovative clean energy firms but, statistically, fewer firms are established per year in the state and those have, on average, a lower rates of company maturation and private sector investment than in comparison state Colorado.

There are clear pathways available to strengthen Maryland's clean energy firms involved in development, commercialization and deployment. Given the evidence regarding support and outcomes in Colorado and New York, Maryland could accomplish a ten-year goal of doubling the rate of formation of clean energy firms each year (from 7 to 14 per year), and cutting in half the rate at which firms fail (from 3.2 to less than 1.6 per year). This could be accomplished with an increase in per capita spending for early innovation (stages 1 and 2) to a level intermediate between Colorado and New York, along with investment to provide developmental support focused on clean energy firms.

SECTION IV

Sources and levels of funding and financing options

The purpose of this report has been to assess the present status of Maryland's clean energy funding in the context of a balance of social and economic development benefits. An overarching observation of the assessment is that Maryland, through its EmPOWER and SEIF programs spends over $400M per year on clean energy programs, none of which is focused on development of in-state manufacturing. Prior to the establishment of MEI[2], there was no dedicated funding to support clean energy innovation by Maryland firms, and the funding provided to Maryland's clean energy firms through general innovation programs averaged only $2M per year. A key conclusion of the report is that *while Maryland is well positioned to derive greater economic benefits from clean energy innovation, the state has not structured its clean energy programs for this purpose.* In the following we highlight the key findings of the report and provide concrete recommendations. The recommendations are focused on developing a Maryland *Clean Energy Innovation System* to strategically leverage clean-technology innovations that foster economic growth and complement the state's strong social commitment to energy efficiency, clean energy and the environment.

IV.A Report Findings and Recommendations

The first high level finding is that, as noted above, the state has failed to exploit the economic development potential of clean energy innovation. The report's first recommendation is for the state to formally define clean energy innovation as one of the state's priorities for economic development.

Recommendation 1

The state of Maryland should diversify its strategic economic development priorities to include multiple technology pillars, beginning by specifically mandating a *Clean Energy Innovation System* that supports innovation, development and in-state manufacturing of clean energy technologies.

The goals for the Clean Energy Innovation System should align with the state's social commitment to energy efficiency, clean energy and the environment, including reduction of greenhouse gas emissions.

The second high-level finding is that the state has narrowly constrained areas of clean energy technologies that can be supported under many of the state's clean energy programs. To obtain the economic benefits of clean energy innovation requires a future-looking focus on energy technologies that enable greater energy efficiency, lower costs for clean energy technology and provide new approaches to reducing greenhouse gas emissions. The report's second recommendation is for the state to endorse a broad definition of the clean energy technology areas to support the economic development opportunities of the future.

Recommendation 2

Future legislative language regarding Maryland's Clean Energy Innovation System should reinforce a broad definition of clean energy to ensure that Maryland has the flexibility to support development of cutting-edge new approaches to meet the state's clean energy and greenhouse gas reduction goals.

A deeper assessment of Maryland's present clean energy programs addresses the lack of coordination and focus on the different stages of clean energy commercialization. Unsurprisingly, since Maryland's clean energy programs were not designed to support in-state development, the state's programs have not been coordinated for that purpose. Establishing such coordination will be essential to success in Maryland's clean energy innovation system, and this is the focus of the report's third recommendation.

Recommendation 3

The State should designate a responsible agency to provide coordination among the agencies that need to be involved in delivering the outcomes expected of the state's Clean Energy Innovation System: Department of Commerce, Public Service Commission (EmPOWER), Maryland Energy Administration, Maryland Energy Innovation Institute, Maryland Clean Energy Center and Maryland Technology Development Corporation.

To clarify the potential outcomes for Maryland's in vestment in a clean energy innovation system, and the steps to accomplish those outcomes, the report's assessment includes a comparison of Maryland with three states (CO, CT, NY) that are peers in innovation and R&D capability, but which have significantly stronger outcomes than Maryland in clean energy innovation. The results indicate that there are clear and concrete steps that Maryland can undertake to deliver desirable clean energy innovation outcomes. In particular, the effective practices in successful states include a balance of *developmental support* and *early stage seed funding*. The developmental support is designed to provide business mentoring, networking and development space for start-up firms. The early stage seed funding is provided to position firms to compete effectively for Federal grants and private sector investment. These findings lead to the 4th and 5th report recommendations.

Recommendation 4

As part of the state's Clean Energy Innovation System MEI^2 should be tasked and funded to deliver developmental support in the form of additional infrastructure and mentoring specifically tailored to the needs of early-stage clean energy firms, using partnerships with MCEC, TEDCO and University venture programs.

Recommendation 5

As part of the state's Clean Energy Innovation System, MEI^2 should be tasked and funded to expand early-stage innovation funding for clean energy firms to a per-capita funding level intermediate between Colorado and New York. MEI^2 should coordinate this program with TEDCO, MIPS, and University venture programs.

The report also includes assessment of the time scale for delivering the state economic benefits of the Clean Energy Innovation System, and the metrics that can be used to monitor progress. Developing, commercializing and deploying new clean energy technologies can require a decade or more, during which time successful firms will attract private investment and begin sales. The responsible agencies involved in the Clean Energy Innovation System will need to establish close connections with Maryland's clean energy firms to track progress. Specific metrics that should be tracked include the number and technology areas of in-state clean energy firms, the progress of firms through the stages of commercial development, and the success of firms in attracting the private sector funding needed to grow. These considerations lead to the 6th report recommendation.

Recommendation 6

The program to create a thriving Clean Energy Innovation System in Maryland should be managed in 5-year stages and assessed against quantitative metrics including growth in firm number, federal and private sector funding per company, and rate and extent of commercial maturation.

The focus of recommendations 4 and 5 is on early stage innovation. However, in the assessments it also became clear that long-term success may be impeded by how Maryland supports the later stages of commercialization, the early deployment and market growth of innovative technology products. At present, Maryland has a substantially lower level of support for early deployment of innovative clean energy technologies than any of the peer states, as well as no mandate to support in-state firms. The heavily constrained requirements for spending in EmPOWER and the SEIF-supported programs is one factor in this issue. The issue of expanding support for early deployment of innovative technologies warrants further consideration, leading to the 7th and 8th recommendations of this report.

Recommendation 7

Given Maryland's unusually low level of support for early deployment of new clean energy technologies, compared with support for mature technologies, the state should require an assessment of the potential for reallocating some EmPOWER funds for emerging clean energy technologies that may provide expanded consumer benefits.

Recommendation 8

The state should require an assessment of the potential for expanded impact of EmPOWER funds by using green finance mechanisms (such as PACE[69], CPACE, Green Bank) for market growth of established clean technologies.

IV.B Proposal for Maryland Clean Energy Innovation System Funding

The recommendations for financing all follow from recommendations 1–3, which are to formally designate Clean Energy Innovation as a state economic development priority, define future-looking clean energy goals and to establish goals and agency responsibilities for a Maryland Clean Energy Investment System. Maryland has successfully used a mechanism of combined tax incentives for investment, dedicated funding through TEDCO, and indirect support via university and other non-profit incubator services for commercialization of innovation in biotechnology. Similar types of support are needed for Maryland's Clean Energy Innovation System.

The first funding recommendation addresses the essential goal for innovative clean energy innovative firms of competing effectively for private sector investment. State Investment incentive tax credits are an effective and relatively low-cost mechanism to help young firms attract investment. Maryland now has two such programs that can be modified under legislative instruction to provide support for clean energy innovation.

Funding Recommendation 1

The state should modify its present Investment Incentive Tax Credits[71] and associated TEDCO Investment Funds[72] to support investments in clean energy technologies. DOC, TEDCO and MEI[2] should be jointly responsible for delivery of Maryland's Clean Energy Innovation System goals through these programs.

Implementation of this recommendation could reserve 10% of the present Biotechnology Investment Incentive Tax Credits for use of biotechnology to address clean energy goals, including bio-agricultural technologies, and treallocate some or all of the presently undersubscribed Cybersecurity Investment Incentive Tax Credit for investments in companies developing innovative clean energy products.

Analysis of the energy innovation programs and funding in peer states provided information on the levels and types of funding needed for successfully establishing Maryland's Clean Energy Innovation system. This information informed the second funding recommendation, and its associated recommendations (2a and 2b) on allocation of support to provide seed funding and developmental programs. The specific recommendation, that the funds should be drawn from the SEIF, would require legislative modification to the authorization for the SEIF.

Funding Recommendation 2

The state should modify the present allocation of the Strategic Energy Investment Fund[70] (SEIF) to include a specific allocation of up to 10% of the Fund's budget to support the Maryland Clean Energy Innovation System, with a renewed authorization considered in 5 years based on demonstrated progress toward goals. Of the reallocated funds, $4.5M should be allocated to the Maryland Energy Innovation Fund (MEIF).

Funding Recommendation 2a

Of the requested allocation from the SEIF to MEIF, $2 M/yr should be designated for expanded direct support of innovative clean energy firms through the *Clean Energy Seed Fund* and the *Partnerships and Matching Fund.*

The expanded *Clean Energy Seed Fund* will provide awards to early stage innovation projects and later stage projects that have demonstrated strong potential to leverage the seed funds to attract additional investment. *The Partnerships and Matching Fund* will provide awards for development of partnerships with industry or Federal laboratories and to provide matching funding for clean tech firms applying for MIPS funding or other programs that require matching funds.

MEI² will lead in coordination with DOC, MCEC, TEDCO, and University Venture programs, and all will be jointly responsible for delivery of Maryland Energy Innovation goals through the seed and matching programs.

Funding Recommendation 2b

Of the requested allocation from the SEIF to the MEIF, $1 M/yr should be designated for developmental support of Maryland clean energy firms through an innovation acceleration program.

MEI² will lead in coordination with MCEC and TEDCO and collaborate with University Venture programs and TEDCO to provide awards for effective programs at Universities and other sites across the state. MEI², MCEC and TEDCO will be jointly responsible for delivery of Maryland Clean Energy Innovation System goals through the innovation acceleration program.

Finally, the Maryland Clean Energy Center (MCEC) is an important resource for clean energy innovation. The MCEC has created a network of clean energy technology stakeholders, designed innovation acceleration approaches, and demonstrated support for commercialization at the early deployment stage using innovative financing. The clear benefits to the Clean Energy Innovation System of expanding MCEC's activities leads to the final funding recommendation.

Funding Recommendation 3

Of the requested allocation from the SEIF to the MEIF, $1.5M/yr should be designated for support for MCEC outreach programs and for use of MCEC's financing and bonding authority to leverage stage 3 deployment of MD-developed clean energy technologies.

APPENDICES

Appendix A: Stages of Commercial Development

A1: Definitions of Commercialization Stages Used for Assessment

Stage 1: Early Innovation/Proof of Concept

Technologies in stage 1 are early stage innovative concepts, often resulting from Federal support at universities and small businesses, with sufficient technical development to indicate a realistic potential to deliver a useful commercial outcome.

Technologies at this stage are too early stage, and thus too high risk, to attract investors. State governments can help these technologies through grants (seed-funding) designed to allow the entrepreneurs to create a proof of concept and preliminary market plan. Additional support exists in the form of matching funding for other development grants (e.g. Federal grants), mentoring (e.g. I-Corps program), or development infrastructure such as early stage incubators.

State support for a stage 1 technology should result in follow-on investment such as angel or venture round A (i.e. graduation to category 2), or purchase or licensing of the technology for further development by an industrial partner or strategic investor. In both cases, entrepreneurial and highly skilled workers with the capability to support further economic development should be retained in state.

Stage 2: Early Commercialization

Technologies in stage 2 have been developed in proof-of concept or early prototype form. They have demonstrated potential to deliver, as system components or full products, improved energy efficiency or clean energy benefits for consumers and society.

Technologies in this category require support for the development of scalable manufacturing capabilities and for demonstration of use under realistic service conditions. They also must develop clear market potential and a pathway to competitive cost.

State government support for stage 2 technologies may include direct funding through publicly operated angel or round-A venture funding programs. Other support may include provision of mentoring and development infrastructure (e.g. technology accelerators), testing facilities, opportunities for demonstration, and investment tax credits.

State support for a stage 2 technology should result in follow on investment such as venture rounds B-E, purchase or licensing of the technology by a strategic partner, and early sales of product. Long-term outcomes should include retention of promising in-state manufacturing and supply companies with correlated high-skill jobs that will grow with as the companies mature.

Stage 3: Early Deployment

Technologies in stage 3 are commercially available and have strong promise to substantially increase energy efficiency and clean energy benefits for consumers and society. Costs may be higher than for alternative products but are expected to decrease as experience with deployment grows.

Technologies in this category have demonstrated manufacturing capability. Deployment, sales and service structures may be early stage, or approaching maturity. Various aspects of regulation, infrastructure and workforce development may still be in development.

Examples in this category include plug-in electric vehicles, off-shore wind, grid-scale energy storage (other than pumped hydro), micro-grids/distributed generation, net-zero buildings, ‘smart’ buildings, ‘smart’ grid, and alternative (zero-carbon) fuels.

State government programs support stage 3 technologies via purchase, tax or investment incentives, support for development of infrastructure, opportunities for demonstration, and favorable finance vehicles.

State support for a category 3 technology should result in growing market viability for the technology. Outcomes should include rapidly increasing market share with concomitant job creation across the supply chain. Establishment of new in-state manufacturing capability and related demand for high-skill jobs is especially desirable. Some stage 3 technologies will mature and provide strong benefits that merit support for further growth of market share under stage 4 programs.

Stage 4: Expanding Market Share (Market Growth)

Technologies undergoing market growth are commercially available and have demonstrable economic benefits to consumers over several years of ownership but may represent a higher up-front cost than alternatives. These products offer clear social benefits in terms of energy efficiency and clean energy.

Technologies at this stage have established manufacturing, deployment, sales and service structures. Regulatory requirements, any required infrastructure, and workforce training are all established. 'Learning' from commercial deployment has helped these technologies move farther along their 'learning curves' and helped bring down costs.

Examples of this stage include Energy Star appliances, HVAC and building insulation, compact fluorescent and LED lighting, and hybrid vehicles. In recent years commercial solar PV and onshore wind farms have matured enough to fall into this category.

State government programs support stage 4 technologies with the primary goal of increasing deployment. Approaches include incentives (such as tax incentives), regulations, grants or favorable financing for consumers, education, and training programs to ease the use of technologies.

Over time, the need for state support for specific stage 4 technologies should evolve. For a given technology, initial support will result in rapid increases in market deployment eventually approach market saturation. At this happens, the amount of state support needed will decline, and support may be reassigned to new technologies that have demonstrated comparable or higher value for consumers and the state. Some technologies that have matured under stage 3 support may move to stage 4 in this way.

A2: Maryland Agencies and Programs: Assessment of Impact on Stages of Commercialization

Agency Programs Supported under the Strategic Energy Investment Fund (SEIF)

Maryland Energy Innovation Fund (MEIF)

In FY2018, $1.5 million in SEIF funds (2.0% of the SEIF funds) were allocated from SEIF to the University of Maryland for the Maryland Energy Innovation Fund (MEIF). As required by the 2017 legislation, the same level of funding will be transferred to the MEIF per year from FY2018 to FY2022 to support the Maryland Energy Innovation Institute (MEI^2) and the Maryland Clean Energy Center (MCEC).

Maryland Energy Innovation Institute (MEI^2) (Stage 1)

MEI^2 is tasked to catalyze and develop clean energy technologies and facilitate the transfer of technologies into marketable products or services. It has established an Advisory Board and an Investment Committee with science, industry, government and economic leaders. MEI^2 provides both developmental support for clean energy innovation, and direct support through grants to start-up companies developing University-derived technology innovations.

MEI^2's Energy Innovation Seed Grants are designed "bridge the gap between academic transformative laboratory research results and prototype demonstrations to obtain investor interest".[73] Thus, we assign the budget for MEI^2 to the "Proof of Concept for Early Stage Innovation" category, which is the 1st level in the commercialization triangle. MEI^2 has provided $400k in seed funding for each of FY2018 and 2019 (funded projects are listed in appendix C).

Maryland Clean Energy Center (MCEC) (Stage 3)

MCEC was originally established in 2008 as a non-budgeted entity, with the purpose of promoting economic development through the clean energy sector. The Center has the authority to charge fees for its programs and receive revenues from financing activities, and statutory authority to issue bonds and lend revenue from bond sales. In the 2017 legislation creating MEIF and MEI^2, MCEC was provided additional authority to carry out convening and networking activities for the Maryland clean energy industry.

MCEC's innovative financing activities have supported technology commercialization at the 'early deployment' stage, at an average of $150,000/yr over the past five years.

Maryland Energy Administration (MEA) (Stages 3 and 4)

The mission of the Maryland Energy Administration (MEA) is to promote affordable, reliable and cleaner energy for the benefit of all Marylanders. The MEA is funded through the SEIF, and was allocated 42.8% of the SEIF budget in FY2018. MEA's programs for achieving their mission create incentives for the purchase of advanced energy technologies, thus generating market pull and expanded deployment of clean energy technologies. Similar to the EmPOWER program, there appears to be no particular focus on products manufactured in-state.

Some of MEA's programs, such as the Clean Energy Communities Low-to-Moderate Income Grant Programs, and Smart Energy Community Programs focus on expanded deployment of clean energy technologies that are well established commercially. In assessing MEA's impact on Maryland's energy technology commercialization pathway, we assign such programs to the 'market growth' category, that is the uppermost (4th) level in the commercialization triangle.

Other programs demonstrate expanded benefits from combining established technologies, such as the Net-Zero Energy Schools and Community Solar and Community Wind programs. Others, such as the Offshore Wind Development Program, Transportation Programs, and Combined Heat and Power programs support the expanded deployment of clean energy technologies that are mature technically, but are early in development of market share. We assign such programs to the 'early deployment' category, that is the 3d stage of development in the commercialization triangle.

Over the past 5 years (Fiscal Years 2014-18), Maryland Energy Administration's annual program spending relevant to technology commercialization was $39.8M, with $22.2M of that in the 'early deployment' category, and $17.6M in the 'market growth' category.

Maryland Department of Human Services (DHS) (Does not support innovation)

The Office of Home Energy Programs within the Maryland Department of Human Services (DHS) uses the SEIF to provide electric utility payment assistance to eligible low-income households. These programs are designed to help make ongoing electric bills more affordable, and does not create market pull for advanced energy technology development. Therefore, we did not include the funds for this program in Maryland's energy commercialization triangle.

Department of Housing and Community Development (DHCD) (Stages 3 and 4)

In addition to implementing the EmPOWER low-income programs, DHCD also uses part of the SEIF for programs that provide homeowners with the resources to improve their homes' energy efficiency. DHCD's Multifamily Energy Efficiency and Housing Affordability Program, and Weatherization Assistance Program expand the deployment of mature clean energy technologies that have been well-commercialized. We assign such programs to "market growth" category, or the 4th level of the commercialization triangle. DHCD also supports the deployment of advanced energy efficient technology with the Energy Efficient Homes Construction Loan (Net Zero Homes) Program. The Net Zero homes program includes advanced energy efficient technology and renewable energy resources, and the program create the market pull for emerging technology, we assign such a program to "early deployment" category, or the 3rd stage of the commercialization triangle.

Over the past 5 years (Fiscal Years 2014-2018), The Maryland Department of Housing and Community Development's annual SEIF-funded program relevant to technology commercialization was $2.1M, with $0.5M of that in the "early deployment" category, and $1.6M in the "market growth" category.

Maryland Department of the Environment (MDE) (stages 3 and 4)

The Maryland Department of the Environment uses the funds from the SEIF for staffing and operations in the Climate Change Program to reduce or mitigate the effects of climate change. Given that this program is not directly related with energy innovation, we do not include it in the commercialization triangle.

MDE also offers the Energy-Water Infrastructure Program (EWIP), which provides grants to water and wastewater treatment plant owners to develop energy efficient and resilient projects. The two focus areas are (1) promoting onsite waste to energy power generation with new combined heat and power systems or other green energy sources (2) replacing or upgrading aging equipment with more energy efficient technologies. These projects support the expanded deployment of mature clean energy technologies, some of which are fully commercialized while the rest are not. Thus, we assign this program into both the 3rd stage and the 4th stage of development in the commercialization triangle.

Over the past 5 years (Fiscal Years 2014-2018), The Maryland Department of the Environment's annual program spending relevant to technology commercialization was $2.4M, with $1.2M of that in the "early deployment" category, and $1.2M in the "market growth" category.

Maryland Department of Transportation (MDOT) (Stage 3)

A credit against the motor vehicle excise tax for qualifying plug–in electric drive (EV) vehicles was approved by the Maryland General Assembly in 2010. In 2011, additional legislation created the Maryland's Electric Vehicle Infrastructure Council. Both the council's authorization and the Electric Vehicle Tax Credit program have been extended through fiscal year 2020. Funds from the SEIF are used to reimburse the State Treasury for EV excise tax credits. We assign this program to the "early deployment" category, which is the 3rd stage of development in the commercialization triangle.

Over the past 5 years (Fiscal Years 2014-2018), The Maryland Department of Transportation's annual program spending relevant to technology commercialization was $1.5M in the "early deployment" category.

Department of General Services

The Maryland Department of General Services (DGS) manages and operates multi-agency State facilities. The DGS Energy Office assists government agencies in developing and implementing green strategies for reducing energy consumption in State buildings. Since it is not directly related with the commercialization pathway, we do not include this in the Maryland's energy commercialization triangle.

Department of License and Labor Regulation (DLLR)

Department of License and Labor Regulation offers the Employment Advancement Right Now (EARN) Maryland program, which supports industry partners with program design to help businesses build the skilled workforce they need. In FY2018, the EARN Maryland Green Jobs Initiative funded four Strategic Industry Partnerships, three of which directly contribute to workforce development relevant to increasing the deployment of clean energy technologies. We thus assign three-quarters of the funding to the "market growth" category.

Over the past 5 years (Fiscal Years 2014-2018), The Department of License and Labor Regulation's annual program spending relevant to technology commercialization was $150,000 in the "market growth" category.

Department of Budget and Management (DBM) and Department of Health

Many state agencies participate in energy performance contracts (EPCs) programs to lower their energy bills. The SEIF is used to repay the loans of the Department of Budget and Management (DBM) and Department of Health. As it is not directly related with the commercialization pathway, we do not include this in the Maryland's energy commercialization triangle.

Maryland Department of Agriculture (MDA) (Stage 3)

SEIF funding is used to support the Animal Waste Technology fund, which is managed by the Maryland Department of Agriculture. The funding is awarded to animal waste-to-energy (WTE) projects, and supports the creation of renewable energy resources and the reduction of nitrogen's movement to waterways. Since the waste-to-energy technologies haven't yet been proven on a commercial scale, the SEIF-funded program supports the "early deployment" of such technologies. We assign this program to the 3rd stage of development in the commercialization triangle.

Over the past 5 years (Fiscal Years 2014-2018), The Maryland Department of Agriculture's annual program spending relevant to technology commercialization was $390,000 in the "early deployment" category.

Programs Supported Under Maryland EmPOWER (Stage 4)

The EmPOWER Energy Efficiency program was established in 2008 to help Maryland's citizens access products and programs reduce their energy costs and improve their quality of life. The program is funded through surcharges on electric power, and it is overseen by the Maryland Public Utility Commission, which provides oversight of delivery of customer benefits and state-wide efficiency outcomes. The EmPOWER programs are delivered by the Maryland Utilities[74] and the Maryland Department of Housing and Community Development. All EmPOWER programs have certain cost-effectiveness, bill impact, environment impact, and job impact requirements.

The EmPOWER Energy Efficiency and Conservation (EE&C) programs incentivize the purchase and use of efficient appliances, HVAC systems, lighting, and building efficiency, etc. As such they create a market-pull mechanism for the most effective clean energy technologies, and thus increase commercial deployment, although the authorization for EmPOWER does not include a focus on products manufactured in-state. The budgets for EE&C programs are included in our assessment of the state budget for market growth, stage 4 in the commercialization pathway. The EmPOWER Demand Response (DR) programs are primarily designed to enable Utility operations in managing demand. While there are many innovative technologies that can be used to support DR programs, based on the documentation for the present EmPOWER DR program, its specific activities do not create significant pull for advanced energy technologies. Therefore, we did not include the funds for this program as contributing to Maryland's energy commercialization pathway. Over the past 5 years (calendar years 2013-17), Maryland EmPOWER average annual program spending was $319M/yr, of which we assess the amount relevant to technology commercialization was $248M/yr, all in the market growth category.

Appendix B: Official Reports Referenced in Preparation of This Document

STATE OF MARYLAND

1. Agency: State of Maryland

Comprehensive Annual Financial Report Fiscal Year Ended June 30 2017"

Retrieved from https://finances.marylandtaxes.gov/static_files/revenue/cafr/cafr2017.pdf

2. 2. Agency: Public Service Commission (PSC) of Maryland

1) "EmPOWER Maryland Energy Efficiency Act Standard Report of 2018 with Data for Compliance Year 2017"

   Retrieved from https://www.psc.state.md.us/wp-content/uploads/Final-2018-EmPOWER-Maryland-Energy-Efficiency-Act-Standard-Report.pdf

2) "EmPOWER Maryland Energy Efficiency Act Standard Report of 2017 with Data for Compliance Year 2016"

   Retrieved from https://www.psc.state.md.us/wp-content/uploads/Final-2017-The-EmPOWER-Maryland-Energy-Efficiency-Act-Standard-Report.pdf

3) "EmPOWER Maryland Energy Efficiency Act Standard Report of 2016 with Data for Compliance Year 2015"

   Retrieved from https://www.psc.state.md.us/wp-content/uploads/2016-EmPOWER-Maryland-Energy-Efficiency-Act-Standard-Report.pdf

4) "EmPOWER Maryland Energy Efficiency Act Standard Report of 2015 with Data for Compliance Year 2014"

   Retrieved from https://www.psc.state.md.us/wp-content/uploads/2015-EmPOWER-Maryland-Energy-Efficiency-Act-Standard-Report.pdf

3. Agency: Maryland Energy Administration

1) "Maryland Strategic Energy Investment Fund Report on Fund Activities Fiscal Year 2018"

   Retrieved from https://news.maryland.gov/mea/wp-content/uploads/sites/15/2019/01/FY18-SEIF-FINAL.pdf

2) "Maryland Strategic Energy Investment Fund Report on Fund Activities Fiscal Year 2017"

   Retrieved from https://energy.maryland.gov/Documents/2017%20Maryland%20Strategic%20Energy%20Investment%20Energy%20Fund%20Report%20FINAL.pdf

3) "Maryland Strategic Energy Investment Fund Report on Fund Activities Fiscal Year 2016"

   Retrieved from https://energy.maryland.gov/Reports/FY16SEIF-Final12_30_16.pdf

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7. Agency: Department of budget & Management

Maryland Budget Highlights FY2016

Maryland Budget Highlights FY2015

Maryland Budget Highlights FY2014

8. Agency: Department of Commerce

FY2017, 2018 Annual Reports, Maryland Department of Commerce

FY2012, 13, 14 Annual Reports, MARYLAND Department of Business and Economic Development

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MSBDFA approved report: commerce.maryland.gov/Documents/ProgramReport/MSBDFA-approved-FY18.pdf

STATE OF COLORADO

Agency: Colorado Energy Office

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Agency: Colorado Department of Revenue

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Agency: Department of Revenue Services

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Agency: Connecticut Energy Efficiency Fund

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Agency: Department of Taxation and Finance

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Agency: NYSERDA

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2) CEF Investment Plan: Building Innovation Chapter

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5) RG&E ETIP 2017-2020

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Appendix C: Examples of Innovative Clean Energy Technologies in Maryland

C-1 MEI² SEED FUNDING PROJECTS

Year	Principal Investigator	University/Company Affiliations	Title
2018	Dongxia Liu	UMD/ Protonic Membranes	Prototype Study of One-Step Membrane Reactor for Stranded Natural Gas to Liquids
2018	Susanna Thon	JHU/ NanoDirect	Large Area Quantum Dot Solar Cells for Building Integrated Photovoltaics
2018	Reinhardt Radermacher	UMD/Mobile Comfort	RoCo – personalized heating and cooling solutions
2018	Stephanie Lansing	UMD/ Plant Found Energy Systems	Biogas Enhancement and Ammonia Extraction for Increased Revenue in Waste-to-Energy Systems
2019	Greg Hitz	UMD/Ion Storage Systems	Packaging of Solid State Batteries for Strategic Partner Testing and Product Integration
2019	Weidong Zhu	UMBC/Talos Industry Corp.	A Novel Geared Infinitely Variable Transmission for Tidal Current Energy Harvesting
2019	Radermacher & Ling	UMD/Mobile Comfort	Stage 2: RoCo for Hot Climates, Grid-independent Operations and Industrial Applications

C-2 ARPA-E PROJECTS

Year	Principal Investigator	University/Company Affiliations	Title
2019	Prof. Jonah Erlebacher	ETCH, Inc.	Carbon Dioxide-Free Hydrogen and Solid Carbon from Natural Gas via Metal Salt Intermediates
2019	Prof. Liangbing Hu	University of Maryland	Superstrong, Low-cost Wood for Lightweight Vehicles
2018	Dr. Abhishek Motayed	N5 Sensors	Digital System-on-chip CO_2 Sensor
2018	Prof. Chunsheng Wang	University of Maryland	Electrochemical Compression for Ammonia Storage and Refrigeration System
2017	Dr. Eric Wachsman	University of Maryland	Solid-State Lithium-Ion Battery With Ceramic Electrolyte

2016	**Prof. Liangbing Hu**	**University of Maryland**	**Highly Conductive, Robust, Corrosion-Resistant Nanocarbon Current Collectors for Aqueous Batteries**
2016	**Prof. Marc Donohue**	**Johns Hopkins University**	**Effect of Adsorption Compression on Catalytic Chemical Reactions**
2015	**Dr. Lei Zhang**	**University of Maryland**	**Integrated, Personalized, Real-Time Traveler Information and Incentive Technology for Optimizing Energy Efficiency in Multimodal Transportation Systems**
2015	**Prof. Jonah Erlebacher**	**Johns Hopkins University**	**Carbon Fiber from Methane**
2015	**Dr. Amir Shooshtari**	**University of Maryland**	**Novel Polymer Composite Heat Exchanger for Dry Cooling of Power Plants**
2015	**Dr. Bao Yang**	**University of Maryland**	**Novel Microemulsion Absorption Systems For Supplemental Power Plant Cooling**
2015	**Dr. Stephen Segal**	**Maxion Technologies, Inc.**	**Tunable Laser for Methane Sensing**
2015	**Dr. YuHuang Wang**	**University of Maryland**	**Meta-Cooling Textile with Synergetic Infrared Radiation and Air Convection for Bidirectional Thermoregulation**
2015	**Dr. Reinhard Radermacher**	**University of Maryland**	**Robotic Personal Conditioning Device**
2015	**Dr. YuHuang Wang**	**University of Maryland**	**Melt Epitaxy of Carbon: A Silicon-inspired Approach to Next-Generation Electrical Wires**
2014	**Dr. Bryan Blackburn**	**Redox Power Systems, LLC**	**Low-Temperature Solid Oxide Fuel Cells for Transformational Energy Conversion**
2014	**Prof. Michael Ohadi**	**University of Maryland**	**A Case Study on the Impact of Additive Manufacturing for Heat/Mass Transfer Equipment used for Power Production**
2014	**Prof. Chunsheng Wang**	**University of Maryland**	**Hyridized Mg2+/H+ Aqueous Battery for Vehicle Electrification**
2014	**Prof. Eric Wachsman**	**University of Maryland**	**Safe, Low-Cost, High-Energy-Density, Solid-State Li-Ion Batteries**
2013	**Dr. Frank Turano**	**Plant Sensory Systems**	**Development of High-Output, Low-Input Energy Beets**
2013	**Dr. John Lettow**	**Vorbeck Materials Corp.**	**Energy-Efficient Hybrid Medium- and Heavy-Duty Vehicle Power Systems**
2010	**Prof. Ichiro Takeuchi**	**University of Maryland**	**Thermoelastic Cooling**

Appendix D: Management and Analysis of Database of State Firms

D1: Data Sources and Technology Categories

Primarily, the dataset was compiled from a number of databases that track innovation by company – i3 firms, the US patent registry, SBIR, awardees, PRIME – in addition to state level organizations such as MIPS and OEDIT. These databases provided various amounts of information on the given company: short and long descriptions of a company's operations, the company founding year, address, etc.

Some of the entries in the databases mentioned above, i3 and patents in particular, have limited clean energy focus. To remove irrelevant companies, we created a list of keywords to flag companies of interest when searching our dataset's descriptions fields. This list of keywords also functioned as a means of sorting the flagged companies into their respective technological categories. For example, companies flagged with high incidences of the keywords "PV," "photovoltaic," "solar," or "perovskite" could reasonably be assumed to be a cleantech company focusing on solar. These categorizations were later checked manually using an online search.

To improve uniformity of data, missing fields were filled manually by referencing additional sources such as Bloomberg, Crunchbase, Linked-in, and news reports.

D2: Identification of Maturity of Clean Tech Firms

Business Phase

The business phase column was created to identify the current state of the company – whether the company was either a *Fundamental R&D & Start up* or a *Mature* company; or rather, if the company had been *Acquired* or since *Closed*.

Fundamental R&D & Start Up – Companies in the early stages of business development. Businesses were assigned to this category if they fit a number of these categories:

- Have not developed a product
- Total revenues less than $5 million
- Do not have an established business structure (executives, board, etc.)
- Founded since 2015
- Fewer than 10 employees

Mature – Established companies with consistent products and customers. Businesses were assigned to this category if they fit a number of these categories:

- Selling product(s)
- Total revenues greater than $10 million
- Publicly Traded Stock
- Have established business structure (executives, board, etc.)
- Founded before 2000
- Greater than 200 employees

Closed – Companies that have closed operations or have been inactive for four years.

Acquired – Companies that have undergone acquisition.

Technology Phase

The technology phase column was created to identify the current state of the company's technology – whether in the early stages *Concept*, *Product Development*, or later stages of *Shipping Product/Pilot* and *Wide Commercial Availability*. Some companies had been previously classified in the I3 database. The following definitions were created to best match these entries:

Concept – Technology has recently been patented and has had little to no product development.

- Recently patented
- No products with given technology

Product Development – The company is actively developing their technology into, but has not yet created, a minimum viable product.

- Product prototypes, made in small scale, subject to alterations
- Published reports on the benefits of tested devices with given technology

Shipping Product/Pilot – The company has established a product and has begun shipping and testing their technology in pilot programs.

- Product or product line with technology are limited to a few companies

- Shipping technology products to customers for pilot / beta testing
- Selling product in limited quantities

Wide Commercial Availability – The technology is widely available, and is well known throughout the industry.

- Established technology prevalent in a large number of companies

D3: Analysis of Funding Timelines

Crunchbase Data Collection – Methodology

Data on investments raised over time was collected from the Crunchbase platform.

1. In order to analyze investments in energy companies, first we identified the companies using two methods:

a) Filtering the description section of the companies provided by Crunchbase. The Crunchbase database of 4,124 companies in Maryland was searched using sixteen categories: wind, solar, efficiency, smart grid, biofuels, utilities, waste, geothermal, hydro, battery, storage, transportation, vehicle, combustion, nuclear, and renewables.

Then, companies that include the above listed expressions were individually reviewed to verify their energy profile.

b) The list of companies was supplemented with additional companies from i3 data. All energy companies from i3 data which were not included in the search described as per a), have been added to the list.

Companies from a) and b), which met the conditions of developing innovative clean energy technologies were further analyzed in terms of investments over time.

2. Final data base includes information of energy companies as follows:
   a) Type of energy technology (solar, wind, etc.)
   b) Organization name
   c) Headquarters location
   d) Description of the company
   e) Estimated range revenue in 2018
   f) Operating status
   g) Founded date
   h) Estimated range of number of employees
   i) Number of funding rounds
   j) Money raised by round

3. In order to present the investment history of Maryland clean tech firms relative to the year of their founding, we specified:

a) Maturity of companies was determined by founded dates and divided into six-time intervals according to the year when money was raised:

I. Investments within one year since founding
II. Investments between year one and two since founding
III. Investments between year two and three since founding
IV. Investments between year three and four since founding
V. Investments between year four and five since founding
VI. Investments in year six and after

Then, we identified the amount of money raised (investments) by each company in periods from I to VII.

b) Based on amount of money raised within each period, investments have been classified into six categories:

I. Below $100k
II. $100k – $1M
III. $1M – $10M
IV. $10M – $20M
V. $20M – $100M
VI. Above $100M

Appendix E: Methodology and Summary of Comparison States

E1: State Comparison Methodology

Identifying Clean Energy Tax Credits, Grant and Loan Programs

To develop a comparison of funding, management, and use of state public energy expenditures among Maryland, Colorado, New York, and Connecticut, the Center for Regional Economic Competitiveness (CREC) examined each state's investments in support of programs targeted to clean energy innovation and commercialization.

CREC began its research by examining the Council for Community and Economic Research (C2ER) State Business Incentives Database[75], a national database of state business incentive programs, to identify clean energy tax credits and grant or loan programs in New York, Connecticut, and Colorado. Furthermore, CREC reviewed the Database of State Incentives for Renewables & Efficiency (DSIRE)[76], a database focused on renewables and energy efficiency incentives and policies funded by the U.S. Department of Energy and maintained by North Carolina State University's Clean Energy Technology Center, to identify additional state incentive programs.

To identify tax expenditures, CREC reviewed annual expenditure reports produced by the respective states' Department of Revenue (see Appendix B for citations): the Annual Report on New York State Tax Expenditures for 2019 produced by the New York Department of Taxation and Finance, the 2016 and 2018 Annual Connecticut Tax Expenditures Report produced by the Connecticut Department of Revenue, and the Colorado 2018 Tax Profile & Expenditure Report by the Colorado Department of Revenue. The Colorado report, which appears to be the only source of data on expenditure estimates published by the state, provides only lower bound estimates for annual expenditures and does not provide detailed information for all tax expenditure programs for all fiscal years observed. Thus, Colorado may actually spend more than what is reported on these programs.

To further identify grant and loan programs and expenditures, CREC reviewed state agency websites and annual reports, program annual financial reports, and investment plan and performance reports. Following are the key reports reviewed and the year of their publication as well as what data those reports provided for this study.

New York's clean energy grant and loan programs and expenditures were collected from New York State Energy Research and Development Authority's (NYSERDA) Budget and Financial Plan (FY2018, 2019,2020). Information on New York's Clean Energy Fund (CEF) and programs through the CEF were collected from the CEF Annual Investment Plan and Performance Report (FY2018) and CEF Investment Plan Chapter reports (2019): Innovation Capacity and Business Development Chapter, Grid Modernization Chapter, Clean Transportation Chapter, and Building Innovations Chapter. CREC also reviewed the NY-SUN Annual Report (2018), RGGI Operating Plan (2018), and NY Green Bank Financial Statements (FY2017, 2018, 2019) for data on sources and investment of funds. Data on New York's utility surcharges that were spent on clean energy was collected from the Energy Efficiency Transition Implementation Plan Reports 2017-2020 submitted by Brooklyn Union Gas Company, Central Hudson, Con Edison, National Fuel Gas, Niagara Mohawk Power Corporation, Orange and Rockland, New York State Electric and Gas and Rochester Gas & Electric, and KeySpan Gas East Corporation.

For Connecticut, CREC reviewed the annual Energy Efficiency Board Programs and Operations Reports (FY2016, 2017, 2018) to identify Connecticut Energy Efficiency Fund (CEEF) grants and loan programs. Funding for these programs are drawn in part from surcharges on investor-owned utilities (IOUs). To identify additional programs, CREC reviewed the Connecticut Department of Energy and Environmental Protection's (DEEP) website. DEEP administers a program portal that houses data on annual Connecticut Hydrogen and Electric Automobile Purchase Rebate (CHEAPR) program expenditures. Those data are presented in a dashboard format and were used in our analysis. In addition, CREC gathered data on programs administered by the Connecticut Green Bank from Connecticut Green Bank's annual financial reports (FY2016, 2017, 2018).

CREC reviewed the CTNext website and identified estimates given for the Entrepreneur Innovation Award Program. CTNext reports the names of companies receiving these grants and the amount that was awarded. Cleantech companies were identified based on information available on companies' websites. The total value of awards given to cleantech companies was tallied each year and included as part of the state's clean energy spending. Connecticut Innovations (CI) furnished anonymized data on cleantech investments, additional information was gathered from CI annual fiscal reports. CREC determined that one of the investments provided by CI did not meet MEI[2]'s definition for clean energy, so that investment was removed from the data set. Investments were categorized into technology development (triangle) stages based on descriptions given by CI and annual investment tallies by stage were generated.

For Colorado, the Colorado Office of Economic Development and International Trade (OEDIT) furnished data on the four Advanced Industry (AI) Grant programs by providing a list of anonymized grant recipients, separated by grant type. The grants include Proof of Concept, Early-Stage Capital and Retention, Infrastructure Funding, and AI Export. The cleantech recipients were separated based on available information on recipients' websites. Colorado utility data was collected from annual reports published by Xcel and Black Hills Energy. This excludes small, natural gas investor-owned utilities (IOUs) that were not available.

To validate identified programs and expenditures, CREC interviewed state representatives to better understand the information available: Kara Allen, Senior Policy Advisor, NYSERDA; Katie Woslager, Senior Manager - Advanced Industries, OEDIT; Peter Longo, Senior Managing Director of Investments, Connecticut Innovations. These interviews provided context, but our findings do not necessarily reflect the views of those representatives.

Categorizing Programs and Developing Funding Triangles

After the collection of program and expenditure data, CREC categorized the programs based on the program's objective and the category of clean energy technological development and deployment, as defined by MEI[2]. The categories include:

- Category 1: Early Innovation/proof-of-concept
- Category 2: Pre-commercial development/early demonstration
- Category 3: Early commercialization/late demonstration
- Category 4: Expanding market development

For this analysis, CREC collected whatever state clean energy expenditures data that were available for the period from FY2014 to FY2019 to calculate program averages for each states' funding triangle. The data were not available for every state for every year. In some cases, the reports were not available due to the way the state reported the information, and in others, data were suppressed due to the small number of taxpayers using the program. So, CREC used whatever data were available to create an average over the years that were available for each category and state. Using those averages, we then calculated an estimated clean energy spending per capita using Census 2018 population data.

It is notable that each of the states used a slightly different mix of years so use of the data should recognize these inconsistencies, and users should add these caveats to any conclusions they draw. The differing time periods could hide key issues that may be difficult to uncover.

First, the averages may mask policy changes that occurred during the timeframe. Rolling averages mask year-to-year changes that can sometimes be very dramatic, reflecting significant policy changes. Data suppressions may be due to lack of use or due to policy limitations placed on programs. Some clean tech policy changes may be external to the state. For example, the New York data only includes data from after the current administration began radically changing Federal level environmental policy, whereas Colorado encompasses three years of the previous administration. Any such exogenous impact to the data could be mis-attributed to state action. For Maryland, we included only one year of data, and that may be greatly influenced by outliers and one-year anomalies.

Second, expenditures in different years are reported in nominal terms. These data do not reflect impacts such as inflation on the data. Combined with other data inconsistencies, the difference could be significant. Furthermore, the states are missing key data elements during the study period. Due to missing data, it is difficult to compare across a single year or even to see trends across year within each state.

Consequently, the comparisons offered are not designed to be exact comparisons of funding levels across states. Instead, they offer approximations for the benefit of understanding how these four states have prioritized investing cleantech dollars in recent years and to help generate a relative size of investment in each of the 4 triangle spending categories. Following describes in detail the expenditure data available from each state and their respective limitations.

Colorado

Colorado expenditures were collected over a five-year period, FY2014 to FY2018. Due to the substantial lack of tax expenditure data, triangle estimates should be considered lower bound estimates. It is likely the state is spending more than what is reported on these programs. The lack of data will most likely impact category 3 and 4 spending estimates, as these areas are most likely to be the targets of tax expenditures.

Connecticut

Connecticut expenditures were collected over a four-year period, FY2016 to FY2019. Connecticut Green Bank loan estimates represent annual accumulated interest and incoming capital from the state. The figure corresponds to new loan money available in each observed year. This estimate captures the year-over-year new investments made by the Green Bank into renewable energy companies and projects. Likewise, the estimates for loan programs administered by CEEF represent newly available capital collected from utility companies through surcharges paid by IOUs.

New York

New York expenditures were collected over a three-year period, FY2017 to FY2019. The Regional Greenhouse Gas Initiative's (RGGI) specific clean energy programs were included in the funding triangle, since RGGI funds may be used to expand program offerings beyond customer's paying into the system benefits charge. Loans within RGGI and the NY Sun portfolio were treated as grants because those are smaller amounts (less than $10M) and are offered at reduced-interest rates. Like the Connecticut Green Bank, the New York's Green Bank loan estimates represent annual accumulated interest and incoming

E2: State Profiles

Colorado Profile

State Clean Energy Policy

In 2004, Colorado became the first state in the country to implement a voter-initiated Renewable Energy Standard. The Renewable Energy Standard requires utilities to produce a certain minimum quota of their electricity from renewable sources. The threshold has been changed several times since the standard was implemented, in 2010 it was increased to 30 percent by 2020. In 2013, the threshold was lowered to only 20 percent.

Governors have historically played a prominent role in determining the state's clean energy policy. Beginning in 2006, the Governor pursued clean energy reform as a central policy platform. His administration focused on encouraging utility companies to transition from coal to natural gas for power generation. Taking office in 2011, the following Governor implemented a methane reduction policy that the Obama administration used as a model for the Federal policy on methane gas emissions. Colorado has the eighth largest solar sector in the country, but coal and natural gas dominate Colorado's energy market; over half the state's electricity comes from coal. Currently, less than 20 percent of Colorado's electrical power is renewably sourced. The current Governor's administration has set a goal of making 100 percent of the state's electrical power produced by renewable sources by 2040. The present Governor has appointed the Colorado Energy Office as the central player for setting the path and strategies to reach this goal.

Traditionally, the Colorado Energy Office has been funded jointly through the state's general budget and a first option on severance tax revenues. These funds were then split by the Colorado Energy Office to support equally clean and renewable energy and more conventional energy incentive programs. Most of the Colorado Energy Office's clean and renewable energy efforts have focused on alternative fuel cars and electric vehicles but has also endorsed community solar projects.[77] Based on the available reported numbers, we estimate that between 2014 and 2018, the Colorado Energy Office spent $1.3M annually on stage 3 technologies.

In addition to the Colorado Energy Office, the Colorado Office of Economic Development and International Trade's Advanced Industry Accelerator program fulfills the most prominent role in the state's clean energy policy. Where other states have chosen to incentivize the purchase of fully commercialized products, Colorado has focused on innovation and entrepreneurialism to advance its clean energy vision through Accelerator grants. This strategy supports initial innovation and the testing of promising technologies of young companies in the state.

Advanced Industry Accelerator

The funds available through the Office of Economic Development and International Trade's Advanced Industry Accelerator provide grants to help companies move innovative ideas through concept development, company formation, to the rollout of commercially viable products.78 The Advanced Industry Accelerator is funded through a portion of state gaming funds and payroll income taxes, and its funds are used to leverage matching private capital.

While OEDIT overall is not specifically cleantech focused, approximately 25% of Advanced Industry Accelerator funds have been awarded to cleantech companies and projects. Cleantech companies then also benefit from the connections to a wider cohort of non-cleantech startups and researchers, leveraging inter-industry experience and knowledge.

There are four grant programs that are administered through the Advanced Industry Accelerator; Proof of Concept, Early Stage Capital Retention, Infrastructure, and Export Accelerator. Proof of Concept grants are awarded to researchers to further the development of promising technologies and research. Recipients must be linked to a technology transfer office in specific university systems and are eligible to receive up to $150k in a three to one matching grant. The majority of the recipients of these grants are medical researchers and biochemists. Between 2014 and 2018, an average of $377,387 per year in grants were awarded annually to stage 1 clean energy technology projects.

Early Stage Capital Retention grants are targeted towards young companies during the potential valley death to develop marketable, innovative products. These grants provide up to $250k, which then can be leveraged for additional venture capital, angle investment, or Federal funds. Between 2014 and 2018, an average of $2,424,030 in grants were awarded annually to stage 2 clean energy technologies.

Infrastructure grants are far fewer in number and on average tend to be larger in both scale and scope than the other Advanced Industry Accelerator grants. Infrastructure grants range between $50k and $500k and are provided specifically to communities on a matching basis, rather than individual companies. These are the most challenging Advanced Industry Accelerator grants to receive.

Export Accelerator grants provide companies with funds to support moving newly developed products from local, in-state markets to interstate and international consumers. The grant reimburses up to $15k in travel and international conference fees for companies interested in expanding beyond the state of Colorado and into exporting.[79] The program includes access to a competitively selected network of global consultants who facilitate the expansion into international markets. Between 2014 and 2018, the Advanced Industry and Export Accelerator grants provided an average of $46,575 in grants annually to stage 3 clean energy technologies.

Utility Energy Efficiency Programs

The state encourages investor-owned utilities to invest in clean energy upgrades through Renewable Energy Standard Adjustment requirements. Investor-owned utilities are permitted to charge an extra 2 percentage retail rate to customers, which the utility can then invest in renewable energy upgrades to reach expected quotas. The state provides the guidelines for what does and does not qualify as a clean energy investment. To date the two investor-owned electric utilities operating in the state, Xcel Energy and Black Hills, have applied the collected funds towards consumer incentives to encourage photovoltaic systems installation.[80]

Xcel also manages the Windsource program; customers pay a slightly increased utility rate with the assurance that for every kWh they consume, Xcel will add a kWh of energy sourced wind to the power grid. Xcel then invests the revenues from the program in wind farm infrastructure and related projects. Between 2014 and 2018, the program invested an average of $70,130,253 annually into stage 4 technologies.

Summary of Colorado Commercialization Triangle

Between 2014 and 2018, the state of Colorado: spent on average $70,130,253 annually in stage 4 technologies, which is $12.31 per capita and 78.3% of total spending in clean energy; spent on average $16,586,665 annually in stage 3 technologies, which is $2.91 per capita and 18.5% of total spending in clean energy; spent on average $2,424,030 annually in stage 2 technologies, which is

$0.43 per capita and 0.27% of total spending in clean energy; spent on average $377,387 annually in stage 1 technologies, which is $0.07 per capita and 0.42% of total spending in clean energy.

Connecticut Profile

State Clean Energy Policy

Connecticut took an early lead in establishing cleantech policies and setting aside state funds to make cleantech and energy efficiency improvements. To support these efforts, the state established the Connecticut Clean Energy Fund — later becoming the Connecticut Green Bank, the first Green Bank in the United States — and the Connecticut Energy Efficiency Fund. For the past twenty years, state utility surcharge funds have been used to meet renewable energy production targets, facilitating state-wide clean energy infrastructure transformation to meet clean energy goals.

However, in response to several state budget shortages, the legislature diverted utility surcharge funds in 2004 and more recently in 2018 and 2019. In 2009 the funds were almost diverted, but funding levels were maintained at the request of the Federal government. The loss of revenue in 2018 and 2019 has prohibited the Green Bank from properly leveraging private investments, an unforeseen complication. The Green Bank and Connecticut Energy Efficiency Fund continued to operate during the years of diverted funding but delayed creating long-term plans, achieving clean energy goals and leveraging private investments. Since the 2018, 2019 diversion, the Green Bank has been working with the legislature to raise clean energy awareness in order to protect sustained funding through utility surcharges.

Connecticut Energy Efficiency Fund

The Connecticut Energy Efficiency Fund is overseen by the Energy Efficiency Board, a group of advisors who evaluate and consult with Connecticut's electric and natural gas utilities to structure and deliver their programs to Connecticut consumers. Fund activities are almost entirely focused on decreasing consumer costs for investments in home weatherization and HVAC upgrades. Additionally, the Fund administers over two dozen grant, rebate, and educational programs that range from business and energy sustainability incentives to residential energy consumption behavioral changes and load response programs. A portion of fund revenues are used to administer cleantech research, development and demonstration grants.

The Connecticut Energy Efficiency Fund is funded through the Combined Public Benefits Charge and Conservation Charge collected by investor-owned utilities from customers, pursuant to legislative requirements. The Connecticut Energy Efficiency Fund also receives a portion of the revenues collected from the Systems Benefits Charge. As mentioned above, a large portion of this surcharge revenue was diverted by the legislature in 2004, 2018, and 2019. While the Fund received enough surcharge revenue to operate its programs, it scaled back planned investments and is reworking its long-term plans.

The Connecticut Energy Efficiency Fund has administered grant money and loans in all categories, except for stage 2 technologies. Between 2016 and 2019, an average $404,802.75 in stage 1 grants, $56.7 million in stage 3 grants, and $124.7 million in stage 4 grants were awarded annually. Additionally, the fund administered an average $10 million in stage 4 loans per year over that same period.

Connecticut Green Bank

The Connecticut Clean Energy Fund supported a wide range of renewable energy programs and encouraged growth in renewable energy supply and demand. It was originally administered by Connecticut Innovations and then moved in 2007 under the administration of the Renewable Energy Investments Board. In 2011, the state closed out the Clean Energy Fund and repurposed the funds to establish the first Green Bank in the US.

To date, the Green Bank has amassed net assets of around $350 million. Interest on outstanding loans cover administration costs, while proceeds from loan paybacks are reinvested into new loans, further growing the asset pool. The majority of the Green Bank's traditional loans are issued to large entities to facilitate energy efficiency improvements and leverage additional private capital in order to meet borrower needs. In addition to traditional loans, the Green Bank also operates a sizable solar lease and loan program for residential consumers and community solar projects. The Green Bank splits revenues from the Systems Benefits Charge with the Connecticut Energy Efficiency Fund. Additional revenue is received from the sale of Renewable Energy Certificates and a portion of the funds derived from the sale of Regional Greenhouse Gas Initiative credits by the state to power companies. This additional revenue was unaffected by the diversion of Systems Benefits Charge revenues in 2018 and 2019.

Most loans issued by the Green Bank are large in scale and intended to facilitate energy efficiency upgrades to stage 4 products. Between 2016 and 2019, the Green Bank provided an annual average of $32.4 million in stage 4 grants and made an average $33.8 million worth of new stage 4 loans per year.

Connecticut Innovations

Connecticut Innovations was legislated in 1989 as a quasi-public investment arm of Connecticut's government. It has evolved into a venture capital firm that invests in start-ups across industries (approximately 4 percent of its current investment portfolio is in cleantech). Until 2007, Connecticut Innovations administered the Clean Energy Fund until the Fund was placed under the oversight of the Renewable Energy Investments Board. Currently, there is no state mandate that sets aside any of Connecticut Innovation's investments for cleantech firms.

Connecticut Innovations does not receive annual funds from the state. Rather, the state intermittently provides funding in the amount of $10 million to $20 million at a time to grow Connecticut Innovations' asset pool. Between 2010 and 2018, the state provided approximately $70 million generated through state General Obligation Bonds

Connecticut Innovations functions as a venture capital fund and actively uses its funds to leverage private capital for investments. From 2016 to 2019, Connecticut Innovations invested $4,865,772 of its $104,385,000 total assets into clean tech firms; approximately 4.6 percent of its total investments.

Between 2016 and 2019, Connecticut Innovations invested in several stage 2 and 3 cleantech companies. During this time, the annual average investment was $997,285.68 into stage 2, and $717,937.57 into stage 3 cleantech companies.

Connecticut Innovations administers two funds in partnership with the University of Connecticut and Yale University. These funds serve as an alternative route for promising companies to receive Connecticut Innovations funding and act as a springboard for startups coming out of the universities that might otherwise not have access to adequate venture funding. For a time, Connecticut Innovations operated a $10M cleantech-specific fund in conjunction with the Department of Economic and Community Development, which was then cut due to budgeting challenges.

CTNext

Mandated by the state, Connecticut Innovations formed CTNext as a wholly owned subsidiary to administer small grants, cultivate incubators, and issue investments of its own. CTNext will receive a total of $67.5 million from Connecticut Innovations and the state of Connecticut by 2021, in annual instalments of $12.35 million. CTNext is not mandated by the state to invest in specific technologies or industries. Between 2016 and 2019, CTNext funded four cleantech companies. CTNext's grant spending appears focused on companies in stage 2. Between 2016 and 2019, it spent an average of $23,666.67 per year on stage 2 grants to cleantech companies.

Other

The state administers several tax incentives to encourage the production and storage of reusable energy. These incentives take the form of sales and use tax exemptions, providing a subtle reduction to cost barriers for the creation and use of renewables. In addition to these subtle nudges, the Department of Energy and Environmental Protection offers the Connecticut Hydrogen and Electric Automobile Purchase Rebate to individuals who purchase hydrogen and electric powered cars. These cash rebates are far more visible than sales and use exemptions and act as powerful encouragement to consumers. The majority of the Department of Energy and Environmental Protection's work focuses on environmental stewardship and protection and falls outside the purview of this study.

Both Connecticut's tax expenditures and the Department of Energy and Environmental Protection's program appear focused on stage 3 technologies. On average, between 2016 and 2019, the state of Connecticut and the Department of Energy and Environmental Protection spent $14 million and $1.2 million per year, respectively, on stage 3 technologies.

Summary of Connecticut Commercialization Triangle

Between 2016 and 2019, the state of Connecticut spent on average $201 million annually in stage 4 technologies, which is $56.27 per capita and 73.1% of total spending in clean energy; spent on average $72.6 million annually in stage 3 technologies, which is $20.34 per capita and

26.4% of total spending in clean energy; spent on average approximately $1 million annually in stage 2 technologies, which is $0.29 per capita and 0.37% of total spending in clean energy; and spent on average $404,803 annually in stage 1 technologies, which is $0.11 per capita and 0.14% of total spending in clean energy.

New York Profile

State Clean Energy Policy

New York has been a leader in clean energy programs since the mid-1990s when it was among the first states to enact laws to increase use of renewable energy, including wind energy, solar PV, and waste-to-energy plants. New York adopted its first renewable portfolio standard (RPS) in 2004. In 2015, the state reached its target of obtaining 29% of electricity sales from renewable sources.[81]

Today, New York state has aggressive plans–largely driven by Governor Andrew Cuomo's leadership–to reduce greenhouse gas emissions. New York has been progressively stepping-up its efforts to modernize utility infrastructure, reduce greenhouse gas emissions and increase the use of renewables to generate electricity.

In 2014, the state announced Reforming the Energy Vision (NY REV) setting out the goals, targets and focus areas for the clean energy sector. REV's ambitious goals to fight climate change include 80% reduction in greenhouse gas emissions by 2050, 50% generation of electricity from renewable energy sources by 2030 and 23% decrease in energy consumption in buildings.[82]

REV initiatives focus on a range of areas such as renewable energy, clean energy financing, grid modernization and storage, transportation, building and energy efficiency. Most programs under REV are designed and implemented by the state agency: New York State Energy Research and Development Authority (NYSERDA). Additionally, state utilities administer a set of energy efficiency programs that are aligned with REV priorities and NYSERDA's clean energy programs. These utility programs were authorized under the guidance of Public Service Commission in 2016. The new authorization provided increased flexibility and responsibility to the utilities in the administration of their energy efficiency portfolios.[83,84] Surcharges collected by the state's nine utilities through their gas and electric portfolios over FY2017-19 supported an average of $247.8 million annually in energy efficiency programs.

NYSERDA and Clean Energy Fund (CEF)

To meet REV's commitments, the state designed the Clean Energy Fund (CEF) in 2016– administered by NYSERDA– as a new framework and a primary funding vehicle to shape the state's energy efficiency, clean electricity and energy innovation programs. CEF replaced existing NYSERDA programs and combined all of NYSERDA's clean energy activities under one comprehensive plan. CEF aims to provide $5 billion in new investment in the statewide clean energy economy over 10 years.

With the CEF, NYSERDA restructured its approach and programs in clean energy. NYSERDA transitioned from one-time project grants and incentives as its primary deployment tools to focusing on creating new market opportunities that will attract private capital investment in clean energy in New York. NYSERDA's strategy currently focuses on leveraging resources from other partners and bringing-in more market players, who can support the larger and faster deployment, and achieve scale, of clean energy technologies and industries, thus helping the state to meet its ambitious goals.

NYSERDA is primarily funded by State ratepayers surcharges through the System Benefits Charge (SBC) on the bills of ratepayers of investor-owned utilities[85] and proceeds from auctions through the Regional Greenhouse Gas Initiative (RGGI). These funds are allocated to the CEF programs.

Consistent with the consolidation of NYSERDA's clean energy activities under the umbrella of the CEF, the Public Service Commission instructed utilities to reallocate SBC collections to CEF funds, administered by NYSERDA. The Public Service Commission's January 2016 CEF legislation established a "Bill-As-You-Go" approach for revenue collection. Under this approach, CEF ratepayer collections and the previously approved collections for New York Energy Smart, Energy Efficiency Portfolio Standard, Technology and Market Development, and Renewable Portfolio Standard programs are held by the electric and gas utilities and used to reimburse NYSERDA for actual CEF program expenses through a monthly reimbursement process.

Through CEF, NYSERDA spends its resources across four portfolios of activity—NY Green Bank (NYGB), NY-Sun, Market Development, and Innovation and Research. The 2016 CEF legislation authorized a ten-year funding of $3.43 billion for the Market Development and Innovation & Research activities, $781.5 million for the NY Green Bank and $960.6 million for NY Sun.[86]

1. NY Green Bank (NYGB)

Founded in 2014, NYGB is a state-sponsored finance entity, working in partnership with the private sector to draw private capital into the clean energy marketplace. NYGB is set-up as a revolving loan fund, whereby it recycles loan repayments into successive investments over time. So far, NYGB has invested about $600 million of state capital and in FY2018-19, it gave out loans of $280.1 million to fifteen new portfolio investments.[87]

NYGB's initial capitalization was established from $315.6 million in uncommitted utility surcharge assessment funds and $52.9 million from RGGI revenues. The CEF legislation has authorized to build NY Green Bank into a $1 billion fund with incremental infusion of state capital. In 2017, NYSERDA also announced that NYGB is pursuing to raise at least $1 billion in third-party capital.[88]

2. NYSun

NY-Sun is a $1 billion initiative providing long term support to the statewide solar industry. This portfolio of programs helps to lower the costs for homeowners and businesses investing in solar power, especially increasing solar deployment among low- to moderate-income communities, lower solar installation costs for customers, and providing incentives for promoting the solar PV industry growth.

NYSERDA's investments mirror its new approach of attracting private capital for market expansion and greater deployment of proven technologies, with the largest commitment in stage 4 technologies financed through the Green Bank and NY-Sun. Between 2017 and 2019, NY Green Bank annually invested an average of $55.5 million in loans to stage 4 technologies, and NYSun invested $43 million annually to stage 4.

3. Market Development

The Market Development portfolio addresses different barriers (such as limited consumer awareness, lengthy approval processes, limited access to finance, etc.) that some clean energy technologies face in market deployment. The programs mostly focus in the areas of energy efficiency, distributed generation, renewable thermal and energy storage.

New York's stage 3 program investments include offshore wind research and development, grid modernization and clean transportation programs. NYSERDA's investments in procuring offshore wind power, and in workforce development and training in offshore wind industry are driven by its big commitment to offshore wind power. Recently it announced a target to produce up to 2.4 gigawatts of offshore wind by 2030, making the largest commitment to offshore wind power by any state in the U.S.[89]

As a part of New York's mandate to use more renewable electricity and transition the state to a carbon-free power grid by 2040, it's been focusing more on modernizing the grid. NYSERDA's High Performing Grid program aims to diversify the supply of clean energy generation resources, enhance overall electric grid performance, and enable customers to reduce their energy costs.[90]

Between 2017 and 2019, an average of $118.7 million in grants were awarded annually to stage 3 technologies.

4. Innovation and Research

This portfolio of programs focuses on technology and business innovation across five key areas: smart grid technology, renewables and distributed energy resources, high performance buildings, transportation, and cleantech startup and innovation development.

Recognizing that firms need support in the early demonstration and early commercialization stages of innovation,[91] NYSERDA's innovation investments help grantees determine technical/business feasibility, assess market opportunities, achieve key product development, and test new technologies at scale. It also provides business incubation, manufacturing support, mentorship, and access to private sector investors and potential development and commercialization partners.

In stage 2 (early commercialization), CEF's Manufacturing Corps (M-Corps) program provides grants to help remove barriers for cleantech hardware startup companies to work with the state manufacturers for manufacturing their products. The Novel Business Models and Offerings initiative supports promising companies in making business model investments to accelerate the deployment of these models.[92] Between 2017 and 2019, an average of $8.1 million in grants were awarded annually to stage 2 technologies.

In stage 1 category programs, CEF provides grants towards a suite of interventions that accelerate the time to market for early-stage clean tech companies through incubators for cleantech ventures, ignition grants, proof-of-concept centers, entrepreneurs-in-residence program and innovation advisors. Between 2017 and 2019, an average of $12.9 million in grants were awarded annually to stage 1 technologies.

Regional Greenhouse Gas Initiative (RGGI)

In addition to the CEF, NYSERDA administers RGGI. RGGI is the first market-based, mandatory cap-and-trade program in the U.S. to reduce greenhouse gas emissions. New York State participates along with eight other Northeast and Mid-Atlantic states in RGGI. These funds are derived from sale of carbon emission allowances and the amount of revenues available is dependent on the auction prices for the allowances. RGGI funds are used by NYSERDA to support CEF, run other energy efficiency, renewable energy and greenhouse gas abatement programs and transfer funds to the Green Jobs-Green New York program. In addition, RGGI funds are used to support clean energy tax credit programs. The New York State Budget for FY2018 directed NYSERDA to transfer $23 million in RGGI funds to the State General Fund to support clean energy tax credits.[93]

Tax Credit Programs

New York provided tax credits of about $43 million annually in 2017-18 in stage 3 and stage 4 categories to incentivize residents and businesses to buy and install solar equipment, install electric vehicle recharging units, use environmentally friendly building materials, and use biodiesel for heating. New York's generous tax credits aim to complement its other grants and loan programs in helping boost the adoption of clean energy by residents and businesses.

Utility Energy Efficiency Programs

Between 2017 and 2019, the state utilities spent an average of $16.5 million annually in grants to stage 4 technologies. The energy efficiency portfolio focuses on meeting specific needs of commercial and residential customer segments through options and opportunities to reduce their energy use. Examples for residential customers include accessing rebates and incentives through market partners, shopping directly through REV demonstration projects such as the Online Marketplace.

Summary of NY Commercialization Triangle

Between 2017 and 2019, the New York state spent on average $526,381,445 annually in stage 4 technologies, which is $26.94 per capita and 79% of total spending in clean energy; it spent on average $118,716,086 annually in stage 3 technologies, which is $6.07 per capita and 17.82% of total spending in clean energy; it spent on average $8,156,947 annually in stage 2 technologies, which is $0.42 per capita and 1.22% of total spending in clean energy; and it spent on average $12,919,164 annually in stage 1 technologies, which is $0.66 per capita and 1.93% of total spending in clean energy.

Appendix F: Interviews and Stakeholder Discussions

Many interviews and stakeholder discussions were used to inform the contents of this report. The individuals and organizations listed in this Appendix were kind enough to talk with members of the teams who worked on this report. The inclusion of their names here does not imply that the individuals or organizations either endorse this report, or agree with any specific views, opinions or statements herein.

INTERVIEWS (UMD)

Interviews included representatives of five small companies in Maryland, representatives of eight small companies or investors in Colorado, and the following:

2/22/19	Colorado Office of Economic Development and International Trade	Katie Woslager	Senior Manager – Advanced Industries	CO
3/13/19	Colorado Cleantech Industries Association	Shelly Curtiss	Executive Director	CO
6/4/19	Colorado Cleantech Industries Association	Ed Williams	Chairman	CO
2/25/19	Colorado Energy Office	Tom Plant	Former Director of the Governor's Energy Office	CO
4/9/19	Colorado Energy Office	Will Toor	Executive Director	CO
9/23/18	Colorado Energy Office	Kathleen Staks	Former Executive Director	CO
6/24/19	Metro Denver Economic Development Corporation	Lisa Hough	Director, Strategic Initiatives	CO

INTERVIEWS (CREC)

8/1/19	Connecticut Innovations	Peter Longo CPA, CFA	Senior Managing Director, Investments	CT
8/28/19	Center for Clean Energy Engineering University of Connecticut	Ugur Pasaogullari, Ph.D.	Professor of Mechanical Engineering, Director	CT
8/28/19	Maryland Department of Commerce	Mark A. Vulcan, Esq., CPA	Program Manager, Tax Incentives	MD
6/4/19	Colorado Energy Office	Andrew Sand	Deputy Director	CO
6/19/19	NYSERDA	Kara Allen	Senior Policy Advisor	NY
7/11/19	Colorado Office of Economic Development and International Trade	Katie Woslager	Senior Manager – Advanced Industries	CO

DISCUSSIONS

8/27/2018	MEI[2]	(members listed below)	Advisory Board*	MD
9/28/2018 3/28/19 6/10/19 8/13/19 (tele-conference)	Maryland Energy Administration	Mary Beth Tung, Chris Rice, Jennifer Gallicchio	Director Chief of Staff Assistant Director of Energy Programs	MD
10/19/2018	Department of Commerce	Paul Spies	Agribusiness and Energy Program Manager	MD
11/8/18	TEDCO	George Davis	CEO	MD
12/18/18 8/21/19	Clean Energy Business Network	Lynn Abramson	President	DC
1/11/19	University System of Maryland	J. Thomas Sadowski, Lindsay D'Ambrosio	Vice Chancellor for Economic Development; Venture Development Director	MD
1/29/19 8/21/19	Citizens for Responsible Energy Solutions Forum	Charles Hernick	Director of Policy and Advocacy	DC
5/8/19	University of Maryland	Julie Lenzer	Chief Innovation Officer	MD
6/7/19	Johns Hopkins University	Sunil Kumar, Jonathan Gottlieb	Provost; Portfolio Director, JH Technology Ventures	MD
6/26/19	Public Service Commission	Amanda Best, Daniel Hurley	Senior Commission Advisor; Director of Energy Analysis and Planning	MD
6/7/19	MCEC	(members listed below)	Board of Directors	MD
7/16/18	CT Green Bank	Bryan T. Garcia	President and CEO	CT
8/7/19	TEDCO	Stephen Auvil, Neil Davis	Executive VP Operations; Director, Entrepreneurial Development	
8/20/19	Public Service Commission	Jason M. Stanek	Chairman	MD
9/11/19	Department of Commerce	Kelly Schulz, Rhonda Ray, Heather Gramm, Jennifer LaHatte	Secretary of Commerce	MD
10/4/19	Baltimore Gas & Electric	Laurie Duhan Erik Ripko	Manager – Energy Efficiency Portfolio and Regulatory Affairs Residential Energy Programs	MD

Members of the MEI[2] Advisory Board

Victor Der

Chair, Advisory Board, Maryland Energy Innovation Institute

Assistant Secretary of Fossil Energy, US DOE (Retired)

Ellen Williams

Vice-Chair, Advisory Board, Maryland Energy Innovation Institute

Distinguished University Professor UMD

Former Director, Advanced Research Projects Agency-Energy (ARPA-E)

Scott Dupcak

Managing Director, Constellation Technology Ventures

Steven Freilich

Science Director, Dupont (retired)

Abigail Hopper

CEO, Solar Energy Industry Association

Geoff Oxnam

Founder & CEO, American Microgrid Solutions, LLC

Chair of the Board, Maryland Clean Energy Center

Philip Perconti

Director, Army Research Laboratory

Mary Beth Tung

Director, Maryland Energy Administration

Members of the MCEC Board:

Geoff Oxnam, Chair of the Board

Founder & CEO, American Microgrid Solutions

Michele Mitch-Peterson, Vice Chair of the Board

Ingenuity Consultant, Siemens Smart Infrastructure

Andrea Pelletier, Treasurer of the Board

Senior Vice President of Commercial Banking, Revere Bank

Mike Gill, Board Member

Portfolio Manager, Cornerstone Advisory

Josh Greene, Board Member

Vice President, A. O. Smith Corporation

Dr. Alex Pavlak, Board Member

Chairman, Future Energy Initiative

Debbie Risher, Board Member

President/Owner/Service Manager, Bel Air Engineering

Dr. Eric Wachsman, Board Member

Director, Maryland Energy Innovation Institute

William L. Crentz Centennial Chair in Energy Research

Dr. Mary Beth Tung, Ex-Officio

Director, Maryland Energy Administration

Workshop

On March 20, 2018, the Maryland Energy Innovation Institute held a workshop on Energy Storage Innovation to provide input for a state-mandated report on the status and opportunities for energy innovation in the state of Maryland. Energy storage[94] was chosen as a revealing example of the potential for energy innovation due to 1) its diversity of applications, including stationary and vehicle storage; defense, aerospace, and biomedical uses; and growing opportunities in the internet-of-things, 2) the economic importance to Maryland of leadership in the modernization of the electric power system, and 3) the rapid technical advances that are underway in improving performance and decreasing cost of energy storage.

WORKSHOP			
SAFT Battery	**Adam Murray**	**Director of Operations**	**MD**
SAFT Battery	**James Herbermann**	**General Manager**	**MD**
Lockheed Martin Corporation	**Mark Alberding**	**Advanced Technology Lead**	**MD**
DNV GL	**Sachi Jayasuriya**	**Consultant**	**MD**
PEPCO	**Shetty Subind (Tom)**	**Manager, Investment Management**	**MD**
PEPCO	**Stephen Sunderhauf**	**Strategic Manager of Customer Programs**	**MD**
CRES Forum	**Charles Hernick**	**Director of Policy & Advocacy**	**DC**
Army Research Laboratory (ARL)	**Cynthia Lundgren**	**Supervisor**	**MD**
Maryland Energy Innovation Institute	**Cathy Stephens**	**Senior Faculty Specialist and Research Coordinator**	**MD**
Maryland Energy Innovation Institute	**Eric Wachsman**	**Professor Director**	**MD**
Maryland Energy Innovation Institute	**Paul Albertus**	**Associate Director**	**MD**
Maryland Clean Energy Center	**Kathy Magruder**	**Executive Director**	**MD**
Maryland Energy Administration	**Chris Rice**	**Director of Energy Program**	**MD**
Maryland Public Service Commission	**Joey Chen**	**Senior Advisor to the Chairman**	**MD**
Advanced Research Projects Agency-Energy	**Max Tuttman**	**Technology-to-Market Advisor**	**DC**
Maryland Technology Development Corporation (TEDCO)	**Jennifer Hammaker**	**Vice President of Business Development**	**MD**
Maryland Department of Commerce	**Paul Spies**	**Agribusiness and Energy Program Manager**	**MD**

Workshop Report

Maryland Energy Innovation Institute Workshop Summary: Innovation Opportunities for the Future of Energy Storage in Maryland

The workshop elicited discussion about innovation opportunities for energy storage from a diverse array of stakeholders, including technology providers, regulators, representatives of utilities and state government agencies, researchers, and others. Many significant points emerged in the discussion:

1) Energy storage provides growing commercial opportunities. Maryland's combination of industrial investments, government laboratories, military installations and University expertise in this area positions it to capture the benefits of in-state commercialization.
    a. The Army Research Laboratory, SAFT and Lockheed Martin have active programs in batteries for energy storage, and offer opportunities for collaborative engagement with University teams and small-businesses in developing, evaluating and demonstrating expanded opportunities.
    b. Coordination of such efforts, possibly led by MEA, could be designed to bring down costs and support expansion of in-state supply chains, workforce and manufacturing capabilities.
    c. The impact of Federal funding at Universities and small companies in this area can be expanded by using seed grants, mentoring and testing opportunities to drive down development risk and thus make follow-on venture or strategic investment more attractive.
    d. State support for early stage technology developers provides a mechanism to retain in-state talent and develop a company base that is more likely to remain in-state.
2) Stationary energy storage for the electric power grid represents serious policy as well as technology issues. The demands on the grid are changing rapidly due to concerns for resilience under extreme weather events (including for high-value, in-state industries such as servers used for cybersecurity), Maryland's renewable portfolio standards (recently expanded to 50% renewables by 2030), expected growth in off-shore wind production, grid congestion in the northeastern part of the state, and economic interest in reducing Maryland's dependence on out-of-state renewable energy credits (RECs) to meet RPS goals. Maryland is now evaluating policy and regulatory barriers to expanded use of energy storage in the grid to help address these and other issues.
    a. State utilities need clear regulatory guidelines before investing in expanded energy storage, including clarification of ownership models.
    b. The Public Utilities Commission must do due diligence in evaluating energy storage as a potential consumer benefit that could be supported under EmPOWER. Utilities are willing to help with such evaluations. Both MEA and DOC could support such assessments by providing opportunities for demonstrations, tests and early deployment.
    c. Early technology demonstrations should be supported in collaboration with users that have stringent requirements for uninterrupted power, and thus less restrictive cost-points.
    d. The DOC should evaluate the benefits of state-incentives for energy storage in the context of attracting to the state businesses that have a strong commitment to reduced emissions or 100% use of renewable power.
    e. Demonstrations of energy storage at the transmission level can be costly, but are needed for sound decision making. State support to encourage cooperative provision of test opportunities involving PJM, the utilities, and technology developers is needed.
3) Numerous states have either committed to, are or evaluating, a shift to carbon-free electricity in the time frame of 2040 to 2050. Along with the recent expansion of the RPS to 50% by 2030, Maryland is also conducting a study of achieving 100% carbon-free electricity by 2040. Reaching such aggressive goals, especially if renewables provide the majority of the carbon-free electricity, may require fundamentally different types of energy storage than are being deployed today (that is, the lithium-ion batteries being deployed today do not have the right performance-to-cost characteristics). This means the development of new stationary storage technologies, especially those that can store electricity for days, weeks, or longer, represents a substantial research, development, and deployment opportunity that Maryland could pursue.

Appendix G: Letters of Support

UNIVERSITY OF MARYLAND
DIVISION OF RESEARCH

7878 Diamondback Drive
Suite B
College Park, Maryland 20742
301.405.2960 TEL

November 7, 2019

To: Governor Hogan, The Maryland General Assembly, The Maryland Energy Administration

I am pleased to provide this letter of support for the call for greater state focus on clean energy innovation as called out in the Maryland Energy Innovation Institute's report on Maryland's Clean Energy Innovation System.

The report calls for recognizing that, in addition to the social benefits of Maryland's strong commitment to energy efficiency and clean energy, clean energy also offers significant economic development opportunities. I have long been a proponent of diversifying our economic strengths by investing in technologies where we collectively possess strong assets, such as in clean energy. Leveraging the state's present investments in this sector to support economic development as well is a win-win proposal.

The report proposes expanded support for Maryland's innovative, early-stage clean energy technology firms, to be administered through the Maryland Energy Innovation Institute. The proposed expansion of the Institute's programs includes building on existing programs, including those of UM Ventures, to provide seed funding and business mentoring specifically tailored to the challenges that early-stage clean energy firms face. If the State approves the expanded program, we will enthusiastically share resources and partner with the Institute to deliver the program while also engaging with other state actors such as TEDCO.

Sincerely,

Julie Lenzer
Chief Innovation Officer

A. JAMES CLARK
SCHOOL OF ENGINEERING

OFFICE OF THE DEAN
3110 Jeong H. Kim Engineering Building
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(301) 405-3868 Fax (301) 314-5908

October 21, 2019

To: Governor Hogan, The Maryland General Assembly, The Maryland Energy Administration

I am pleased to endorse the findings and recommendations of the Maryland Energy Innovation Institute's mandated report on Maryland's Clean Energy Innovation System. The report demonstrates the growing potential of Maryland's engineers and scientists to prepare high-impact energy innovations for commercialization, creating new in-state firms that will create high-quality jobs in research and manufacturing. The report also documents the historical imbalance in Maryland's support of innovative new technologies, which has squeezed out developmental support in areas outside of biotechnology. I strongly endorse the report's recommendation that Maryland support a broader spectrum of innovative technology areas including clean energy technologies.

The University of Maryland has been pleased to host the Maryland Energy Innovation Institute. Thc proposcd cxpansion of thc Institutc's Programs, which includes important linkages with University Venture programs (MTECH and UM Ventures at University of Maryland) is well thought out and will deliver valuable outcomes. If the State approves the expanded program, the College of Engineering will enthusiastically support the Institute in delivering the program, including ensuring strong, constructive interactions with MTECH.

Sincerely,

Darryll J. Pines, Dean and Farvardin Professor
A. James Clark School of Engineering
University of Maryland
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November 1, 2019

To: The Honorable Larry Hogan,
Governor of the State of Maryland
The Maryland General Assembly
The Maryland Energy Administration

From: Amitabh Varshney, Dean Amitabh Varshney

Re: MEI2 Energy Innovation Report

I am pleased that one of our Distinguished University Professors, Ellen D. Williams, has been able to serve the State by leading the development of the Maryland Energy Innovation Institute's report on Maryland's Clean Energy Innovation System. Prof. Williams' background, which includes serving as the Chief Scientist of BP and the Director of the Advanced Research Projects Agency – Energy, makes her uniquely qualified to support the State in planning its clean energy innovation focus.

The report highlights Maryland's strong university research and development programs, its ranking as one of the most innovative states in the nation, and recent demonstrations of creative clean energy innovation in start-up firms within the State. Using comparisons with other states of similar innovation ranking, the report presents concrete recommendations on how to increase the number and health of clean energy firms, and thus deliver to the State the economic development benefits of in-state development and manufacturing of advanced clean energy products.

I am happy to endorse the report's recommendations to increase support for the transition of cutting-edge research results from the State's universities to in-state firms that will develop and deploy those results for the benefit of the State and society as a whole.

JOHNS HOPKINS
UNIVERSITY

Date: November 7, 2019

To: Governor Hogan, The General Assembly, The Maryland Energy Administration

Johns Hopkins University is strongly committed to the principle that the outcomes of curiosity-driven basic research should, when ready, be developed commercially for the benefit of society. This commitment is demonstrated in our dynamic Johns Hopkins Technology Ventures programs. We take the issues of climate mitigation and clean energy very seriously, and the recommendations proposed in the Maryland Energy Innovation Institute's report would create opportunity for even more innovation.

I am pleased to see the rigorous, data-driven approach of the Maryland Energy Innovation Institute's report because it provides a solid basis to inform decision making. The proposal and goals for expanded seed funding and developmental support for Maryland firms with innovative new clean energy technologies are well-designed to deliver impact. Seed funding creates leverage for small firms in finding Federal support such as ARPA-E and SBIR awards, and developmental support provides young firms with business mentoring and networking opportunities essential to attracting private sector investment and bringing their new products to deployment.

As a result, I am happy to support the report's recommendations for strengthening Maryland's Clean Energy Innovation. If the new programs are approved by the state, Johns Hopkins Technology Ventures will actively participate in delivering successful outcomes.

Sincerely,

Sunil Kumar
Provost and Senior Vice President for Academic Affairs

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November 18, 2019

The Honorable Larry Hogan
Governor of the State of Maryland
100 State Circle
Annapolis, Maryland

Dear Gov. Hogan:

Today, no less than in 2005 and 2010 when I led the preparation of Federal reports on "Rising Above the Gathering Storm" regarding America's competitiveness in advanced technologies, I remain committed to the importance of this subject for our citizens' standard of living and access to high-quality employment. Clean energy, including the creation of ARPA-E, were areas of advanced technology highlighted in the Gathering Storm report, and remain important today both economically and in terms of mitigating the drivers of climate change. In this context, I am pleased that Maryland's outstanding Universities and small companies have performed highly competitively in gaining awards from ARPA-E, awards that are designed to move innovative early stage technologies onto the pathway for commercial development and deployment.

Similarly, it was my honor to chair, on the behalf of the State of Maryland, a study of means to increase our State's competitiveness and economic growth. The ultimate impact of Maryland's growing innovation strength will need the State to complement its commitment to the societal benefits of clean energy with a parallel focus on in-state clean energy research and manufacturing as an economic development opportunity. In recent years, the State has devoted about $400 million per year jointly on its EmPower programs and Strategic Energy Investment Fund programs, but none of that funding is authorized for support of in-state commercial development of advanced clean energy technologies. The relatively small amount of state funding, $2 million per year, that has supported early-stage clean energy innovation is not sufficient to deliver the potential economic impacts of Maryland's clean energy entrepreneurs.

The Maryland Energy Innovation Institute's recent report documents higher levels of clean energy funding in states that are Maryland's peers in innovation and have demonstrably stronger outcomes in commercial development of advanced clean energy technologies. The report recommends modest increases in Maryland's funding for early-stage innovation, to be used in well-planned programs that will increase the number, health and productivity of the state's clean energy innovation firms. I believe this recommendation strongly serves our State's best interests.

More broadly, the Maryland Energy Innovation Institute report recommends that the State include a healthy and effective Clean Energy Innovation System as one of the pillars of its Economic Development priorities. I strongly support this recommendation as well as the above recommendation. Along with the expanded support for early innovation, these proposals can be used as the starting point for expanding the role of in-state clean energy research and manufacturing firms in Maryland's economic future.

Sincerely,

Norman R. Augustine

Also to:

Ms. Mary Beth Tung
Director
Maryland Energy Administration
1800 Washington Blvd., #755
Baltimore, MD 21230

Senator Thomas Mike Miller, Jr.
President
Maryland General Assembly
State House, H-107
Annapolis, MD 21401 – 1991

Endnotes

1 ITIF State New Economy Index, 2017; Bloomberg State Innovation Index 2019.
2 Source: NSF Survey of state government research and development, https://www.nsf.gov/statistics/srvystaterd/
3 R. Adams, J. Pless, D.J. Arent, and K Locklin, "Accelerating Clean Energy Commercialization: A Strategic Partnership Approach," Technical Report: NREL/TP-6A60-65374, April 2016
4 "Clean Tech 3.0, Venture Capital Investing in Early Stage Clean Energy, A Changing Investment Climate," 2017, https://www.ceres.org/resources/reports/clean-tech-30-venture-capital-investing-early-stage-clean-energy
5 D.M. Hart, Across the Second Valley of Death: ITIF report 2017.
6 See Figure II-4 and related text. Between 2013 and 2017, TEDCO's annual support varied between $400k and $1.6M, while MIPS annual support varied between $620k and $2.1M.
7 SBIR = Small Business Innovation Research; STTR = Small Business Technology Transfer
8 The addition of MEI^2's $400k seed fund to the historic annual average support from MIPS and TEDCO, would increase Maryland's stage 1&2 spend to $0.40 per capita.
9 Maryland's ratio is 10.3 to 1, CT's is 2.8 to 1, CO's is 4.2 to 1, NY's is 4.4 to 1.
10 See Figure III A and related text. From 2001-2017, MD rate of new clean energy firm formation was 7/yr , and the rate of failure for firms 5 or more years old was 2.2/yr .
11 PACE = Property Assessed Clean Energy, CPACE = Commercial PACE.
12 For example: Cyber and Biotechnology Investment Incentive Tax Credits.
13 For Example: the Cyber Security Investment Fund and the proposed Technology Infrastructure Fund.
14 * Total MEI^2 budget is $1.5M/yr with $900K/yr of that going to MCEC for green bank and stage 3 & 4 activities
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33 National Science Foundation, National Center for Science and Engineering Statistics. 2019. "National Patterns of R&D Resources: 2016–17 Data Update." 19–309. Alexandria, VA: NSF. https://ncses.nsf.gov/pubs/nsf19309. Note(s): (a) Business R&D includes own funds, Federal sources of funds, as well as non-Federal sources of funds (i.e., other companies, universities, or research centers located in or outside the United States, and state government agencies). (b) Higher education R&D includes Federal, other government, business, higher education, nonprofit, and other sources of funds. (c) FFRDC R&D includes Federal and non-Federal sources of funds (i.e., state and local governments, business, nonprofit organizations, and all other sources). (d) Non-profit R&D only includes Federal sources of funds. (e) State R&D represents internal performers in support of an internal R&D project (e.g., by state agency and department employees or services performed by others).
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67 Definitions used for assigning companies to stage of maturity are presented in appendix A.
68 Add reference to Crunchbase data sourcing.
69 PACE = Property Assessed Clean Energy, CPACE = Commercial PACE.
70 FY2018 budget $76.8M, FY2019 budget $85.5M
71 For example: Cyber and Biotechnology Investment Incentive Tax Credits.
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75 C2ER State Business Incentives Database – http://stateincentives.org/
76 Database of State Incentives for Renewables & Efficiency (DSIRE) - https://www.dsireusa.org/
77 ***add web page title, originating organization ** https://drive.google.com/file/d/0B7w3bkFgg92dMkpxY3VsNk5nVGZGOHJGRUV5VnJwQ1U4VWtF/view
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83 2015 New York State Energy Plan, https://energyplan.ny.gov/Plans/2015.aspx
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92 2019 CEF Investment Plan: Innovation Capacity and Business Development Chapter
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MARYLAND ENERGY
INNOVATION INSTITUTE